# THE IRON AND STEEL MAGAZINE

SUCCESSOR TO THE METALLOGRAPHIST

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THE IRON AND STEEL INDUSTRY

EDITED BY
ALBERT SAUVEUR

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## INTRODUCTORY

T HE *Iron and Steel Metallurgist and Metallographist* is an outgrowth of *The Metallographist*. When the parent publication was first issued its purpose and scope were set forth in an introductory article in which it was contended that metallurgists, engineers, chemists, and scientists in general, interested in the new and growing science of metallography, found it very difficult to keep informed as to its progress, because of the necessity of perusing numerous publications in which articles on metallographic subjects were liable to appear. One of the aims of *The Metallographist* was, therefore, to " present to its readers every three months, a clear, exhaustive, and comprehensive review of what had been accomplished in metallography during the previous quarter."

The favor with which the magazine was received, its steady growth, the many words of encouragement, have been a source of much gratitude to the editor. He has found in these unmistakable marks of appreciation conclusive evidences that his efforts were not sterile, his conduct of the journal not unsuccessful. The editor will perhaps be permitted to reproduce here one of the many unsolicited expressions of appreciation which he has received. Had it been the only one he would have considered it liberal compensation for his efforts:

" I cannot tell you how much delighted I am with the *Metallographist*. It is a most precious publication. Hardly a day passes that I do not refer my students to it. I give more references to that, I think, than to all other publications together, and I found in Europe that this admirable work of yours was very highly appreciated.    HENRY M. HOWE."

It is the purpose of the publishers of *The Iron and Steel Metallurgist* to do for those interested in the iron and steel industry generally what *The Metallographist* has so successfully done for students of metallography. The new magazine will be a monthly publication of approximately one hundred pages of descriptive matter devoted to the Iron Industry in its various branches, including blast-furnace practice, foundry work, steel making, the treatment of steel, physical and chemical testing, the properties of iron and steel, statistics, etc.

The publishers appreciate the fact that the value of the magazine will depend to a large extent upon its exhaustive character. In order to cover the entire field, not only in this country but abroad, they have arranged to receive from specially qualified correspondents, located in the various metallurgical centres of Europe and America, monthly reports of the development of the industry. Beside this feature, which should prove of great interest and value to all iron and steel men wishing to keep abreast with the times, there will be a considerable portion of the magazine devoted to original contributions. These will be from the pens of thirty or more of the most eminent metallurgists of the world, each of whom has assured the publishers not only of his good will but of his willingness to coöperate in any possible way in making the new journal a success. It is believed that the articles of these specialists alone should be enough to make the magazine indispensable to every iron and steel producer and user in the country.

Moreover, the technical press, both foreign and domestic, will be closely examined for items and articles pertaining to iron and steel. The most important of these articles will be published in full, while the substance of those of lesser moment will be presented by carefully made abstracts. The original magazines containing these articles will be kept on file in the publication offices, and duplicates may be had by subscribers at any time. There will also be published reports of the proceedings of engineering societies, especially those of the British Iron and Steel In-

stitute and the American Institute of Mining Engineers, and a systematic review of the more important iron metallurgical books and pamphlets of the month will be included in each issue. Moreover, the field pertaining to Metallography, not only of iron and steel but of other metals and alloys, will be covered thoroughly and exhaustively; and, although *The Metallographist* will cease to exist as an independent quarterly publication, it will, as a part of the new magazine, continue to live, and by reaching a larger field will promote even more than heretofore the progress of the science.

It will, in short, be the constant endeavor of the publishers to make the reader feel that through the perusal of *The Iron and Steel Metallurgist* no article of value pertaining to the metallurgy of iron and steel, no happenings of importance in the iron world, will escape his notice. Notwithstanding their realization of the boldness of the undertaking the publishers feel confident that they can conduct the journal in a manner that will warrant support and encouragement on the part of those interested in this, the greatest of all Industrial Arts.

## IRON AND STEEL ALLOYS

By R. A. HADFIELD

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IN response to the editors' kind invitation, the writer has much pleasure in contributing the following remarks to their new issue, to which he wishes every success. *The Metallographist* in the past has been of great service to the craft, and the writer hopes that this larger venture will have all the success it so well deserves.

The writer will deal with a subject of which he has made a special study during the last fifteen years, namely, as to the effect of various elements upon the metal iron. When commencing his work towards the middle of the eighties of the last century, there was practically no light or information in this direction, outside the influence of carbon upon iron. The only research at that time, and on a comparatively small scale, was made by the Terre-Noire Co. of France, whose research work was carried out by those pioneers of scientific investigation,

Messrs. Euverte, Pourcel, and Gautier. The metallurgical world owes a great debt of gratitude to these early workers. In the use of iron, therefore, the latest, and not the least important, phase of development has been found in its alloys or compounds with other elements. This study is perhaps one of the most fascinating of all its branches of research, and Metallurgists are continually endeavoring to improve and strengthen their beloved metal " ferrum " by giving it higher tenacity, elasticity, and greater hardness, without sacrificing the valuable and inherent toughness of the metal.

There is no doubt that the comparatively soft metal " iron " in itself would be of little service to the world at the present day in face of requirements which necessitate a material possessing resistance to much greater stresses and wear and tear than formerly. Professor T. Turner has shown that the pure metal iron is not considerably harder than copper, nor is it very much stronger as regards tensile strength. It can, therefore, be readily imagined how in itself such a metal would render impossible that combination of high speed with greater wear and tear for uses which are the result of modern mechanical progress of all classes. Without doubt, further developments will largely depend upon the material which the Metallurgist can offer for utilization by the civil, mining, mechanical, or electrical engineer.

It need also hardly be said that such progress renders necessary a development which becomes each year more complex and requires more specialization of research. The problems to be solved present a field in which results at all approaching to finality are very far away, and can only be attacked little by little.

In a paper read by Professor Arnold before the Iron and Steel Institute, upon " The Physical Influences of Elements on Iron," he pointed out a number of interesting and valuable facts relating to alloy steels. A series of thirteen alloys were prepared, including cast and forged pure iron, also iron alloyed respectively with as nearly as possible 1½ per cent of each of the following elements: carbon, silicon, aluminium, manganese, nickel, copper, chromium, tungsten, arsenic, phosphorus and sulphur. A most exhaustive series of mechanical and microscopical tests were undertaken, offering a remarkably unique correlation. The writer has plotted Professor Arnold's data in the following diagram (Fig. 1).

From this can be readily seen the particular effect of each element. Whilst these tests do not give the effect of wide varia-

tions in the percentages of each element upon iron, they are in themselves of service by showing the results obtained by the addition of one particular percentage, and that percentage not often usually exceeded in practical use as regards several of the elements.

The properties of the principal iron alloy, carbon steel, are



| | FT.FORGED | C. | NI. | MN. | CU. | CR. | W. | AL. | SI. | AS. | P. | S. | FE.CAST |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPECIAL ELEMENT | 89·87 | 1·35 | 1·51 | 1·29 | 1·81 | 1·10 | 1·41 | 1·85 | 1·94 | 1·57 | 1·36 | ·97 | 92·62 |
| CARBON | ·04 | 1·35 | ·11 | ·10 | 10 | ·17 | ·08 | ·03 | 08 | ·04 | ·07 | ·08 | 08 |
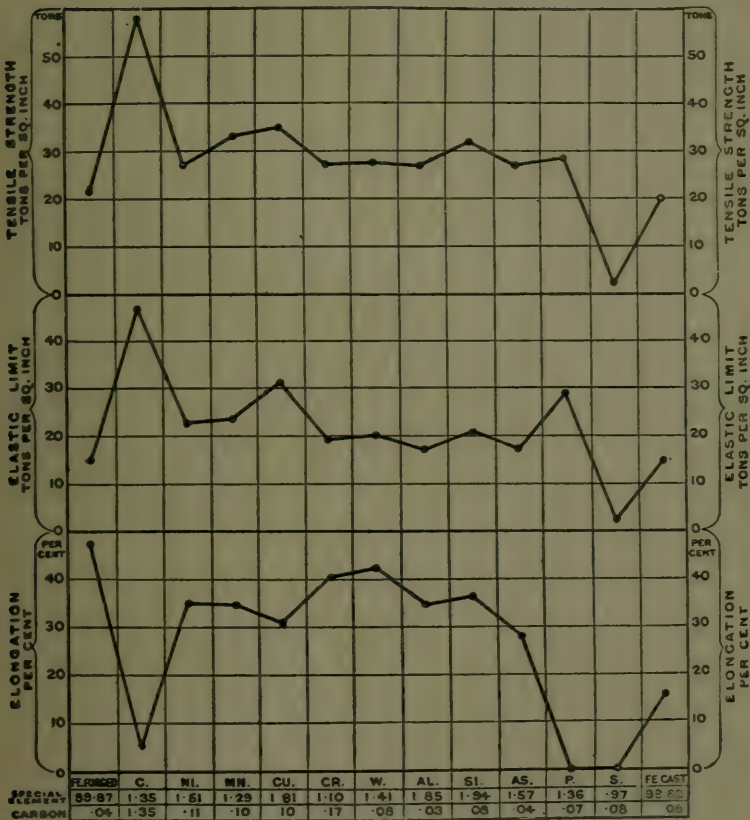
Fig. 1

well known, and only need a general reference here. Purity of material still holds the field for the production of the highest and best quality of carbon steel. The late Sir F. Abel, by a number of valuable researches, contributed to the Iron and Steel Institute, the Mechanical Engineers, and other Societies, did specially important work in this direction, for which the Iron and Steel Institute wisely awarded him the prized recognition of the Bessemer

Gold Medal. This work has also been continued and amplified by Professor Arnold, Messrs. Stead, Howe, Sauveur, Benneville, Hogg, and Spencer, and on the Continent by those exceedingly able investigators, Messrs. Osmond, Dumas, Heyn, Charpy, Guillaume, Guillet, and others.

The writer's paper on " Alloys of Iron and Manganese," read before the Institution of Civil Engineers in 1888, was the first systematic research as to the influence of a special element upon iron. This was followed by a similar paper to the Iron and Steel Institute in the same year. Then " Alloys of Iron and Silicon " in 1889; " Iron and Aluminium " in 1890; a paper read at New York, 1892, " Iron and Chromium "; " Iron and Nickel," 1899; and 1903, " Iron and Tungsten." He has also made a number of researches upon iron with other elements, including copper, cobalt, molybdenum, titanium, and other elements, which will be briefly referred to in the present contribution.

As regards alloys of iron and manganese, the product now known throughout the world as " Hadfield's manganese steel " has grown to a large and important industry, as the material supplies a want met by no other known material. The effect of manganese upon iron and a certain percentage of carbon, 0.80 per cent to 1.40 per cent, in the material known as manganese steel, containing about 12 per cent manganese, is to produce a material possessing to a peculiar degree combined hardness and toughness.

This metal manganese has a very extraordinary effect, as on increasing the addition beyond the usual percentage, say under 1¼ per cent, brittleness gradually occurs, until on reaching about 5 per cent and up to about 7 per cent the product is exceedingly brittle, whether in the cast or forged condition, and no treatment has yet been discovered which can remove that objectionable property. The quality of toughness, aided by suitable heat treatment, greatly increases after 7 per cent is passed, the maximum, in the presence of 0.80 per cent to 1.20 per cent of carbon, being reached at about 12 per cent manganese.

Thus it may be well said that not the least important phase of development in the use of iron has been found to arise from the study the writer instituted as to the effect of iron alloyed or compounded with other elements.

At the inception of his new material, manganese steel, no one took more pains than the writer to point out that, owing to its

peculiarities, it would require long and careful study to master the difficulties in its production and application.

Happily these difficulties have been largely overcome, and its increasing application in England, America, and elsewhere, fully justifies the great labor bestowed in fighting the early difficulties met with, both in its application and manufacture.

The writer recognizes that, as regards America, the help given by that indefatigable masterer of difficulties, Professor H. M. Howe, and also by his own licensees, the Taylor Iron & Steel Co., has been very great, and much credit is due to them for the assistance they have rendered.

The peculiar non-magnetic qualities of manganese steel still offer a problem not easy of explanation. That excellent band of French workers, Messrs. Osmond, Dumas, Charpy, Guillaume, and Guillet, have labored in a most admirable manner to try and solve this problem, and, of course, if it be admitted that iron can assume more than one form, a theoretical explanation is not so difficult. This particular question has also been studied by them in connection with the peculiarities of certain high percentages of nickel alloyed with iron. The reversibility of the magnetic qualities of these alloys is much greater and more easily effected than in manganese steel. For example, nickel steel, containing about 25 per cent to 33 per cent of nickel, can be made magnetic or non-magnetic by subjecting to extremely low temperature ( — 60° C. or less) and restored by raising the temperature. Manganese steel, however, is not subject to this rapid change, and the same explanation of the changes they have noticed would hardly seem to hold good. The writer would rather say that the changes effected, at any rate, in manganese steel, are due to changes in the condition of the carbide or the double carbides of iron and manganese.

*Alloys of Iron and Silicon.* — No great application has been found for this, that is, for comparatively high percentages added to iron, though experiments that may prove of extreme importance regarding the effect produced by silicon upon the magnetic properties of iron are in progress.

The old fear that silicon caused iron to be brittle has been exploded, at any rate when there are only present small percentages of carbon. In the presence of carbon, say 1 per cent, especially if such an element as chromium is also present, a very intense hard-

ness is obtained, which has been made considerable use of practically. Steel containing 2 per cent of silicon and 1 per cent of carbon hardens in the same way as chromium and tungsten steel, though probably not so intensely, but it is tougher. When it is remembered that 2 per cent of silicon in cast iron prevents any chilling effect, that is, prevents the carbon from combining with the iron, it is somewhat remarkable to find that the same percentage in steel in the presence of much less carbon — probably one-third less — not only does not prevent the hardening of the steel upon quenching, but rather assists it. This is a striking anomaly difficult to understand or explain with our present knowledge.

*Alloys of Iron and Aluminium.* — The effect of aluminium is very similar to that of silicon. It is very remarkable that even with as much as 2 per cent to $2\frac{1}{2}$ per cent present of either of these elements, no less than 30 per cent elongation can be obtained. It is probable, however, that the value of this elongation is somewhat fictitious, and that under sudden shock, for example, the Frémont test, the material would have much less value than that apparently represented by its elongation under static stress.

The relative advantages of these two elements for obtaining soundness is now well known. The writer many years ago stated that if it were possible to obtain pure, or comparatively pure silicon, its use would be found almost as beneficial as aluminium is now being proved to be, and thanks to the aid given by the electrical furnace in producing high percentage silicon alloys such material is now available.

*Alloys of Iron and Chromium.* — Chromium has been found a very useful element, and the success obtained with projectiles and armor-plates containing it has been very great, specially when alloyed with nickel. Here again, however, the mere addition of chromium alone in the absence of carbon has not been found to offer any special benefit. A chromium steel without carbon will not harden, but in the presence of carbon the hardening action is very energetic. The metal chromium seems, therefore, to have the power of causing the formation of intensely hard carbides of iron or double carbides of iron and chromium. The most striking example known to the writer of its use in conferring great stiffness without interfering with toughness was shown a few years ago in the case of a 6″ armor-piercing shot made by his firm. This shot was fired at a 9″ compound plate, which it perforated, remaining

unbroken. It was again put into the same gun and fired through a second plate of the same thickness, and the shot still remained unbroken, and was fired a third time. Quite recently his firm fired a 4⅛″ calibre capped shot unbroken through a 5″ K. C. plate, a somewhat remarkable performance.

*Alloys of Iron and Nickel.* — The use of nickel is now very considerable, and has been very fully dealt with in the author's papers on " Alloys of Iron and Nickel." There is no doubt that the increased tenacity and higher elastic limit obtained with nickel steel subjected to proper heat treatment represents a very important gain, though the writer knows that, even to-day, several of the leading manufacturers of gun tubes still adhere to plain carbon steel, properly heat-treated and oil-toughened.

Alloys of nickel and iron are probably the only ones which, no matter what percentage of either metal is present, are forgeable. It might be expected that this would naturally be so, both metals themselves being malleable, but in the case of iron and copper both these metals are malleable, yet iron-copper alloys cannot be forged when the copper present exceeds about 3 per cent or 4 per cent.

*Alloys of Iron and Tungsten.* — The writer has recently contributed to the Iron and Steel Institute (September Meeting, 1903) a paper on " Alloys of Iron and Tungsten." He has there attempted to treat the subject exhaustively, including the historical as well as the practical side of the question. No less than 500 separate tests were made upon the various alloys produced, ranging from 0.10 per cent to 16.18 per cent tungsten, and including the examination of the material in the cast and forged condition, its qualities under compression, bending and tensile stresses, also electrical, magnetic and other tests.

It is difficult to sum up briefly the results obtained in a lengthy research of this kind, but one of the important points it has brought out is that mentioned by Professor Barrett, viz., that the metal tungsten affects iron to a lesser degree, as regards reducing conductivity, and therefore electrical resistance also, than any of the various elements yet added to iron. This is an important point, as many important physical qualities are more or less determined by this factor.

As regards the effect of tungsten upon the mechanical qualities, the research mentioned proves that tungsten up to 10 per cent or 12 per cent and in the absence of carbon, has but little in-

fluence upon the elastic limit, nor is the tenacity raised so much as might have been expected. A specimen containing only 0.05 per cent carbon, and 18.70 per cent tungsten, which was kindly furnished to the writer by Professor Arnold, gave 28 tons elastic limit, 51 tons tenacity, 21 per cent elongation, and 42 per cent reduction of area. The value of the elongation in itself was somewhat fictitious, as under the Frémont test, which so well brings out the real toughness of the material under examination, the specimen only showed a strength of 12, as against 22 to 26 kilogrammetres for mild steel, and 40 kilogrammetres, with the specimen still remaining unbroken, for the Hadfield " Resista " steel, that is, a nickel-manganese-iron alloy.

*Alloys of Iron and Cobalt.* — The writer was the first ever to produce cobalt steel, namely in the year 1891. The tests were of considerable interest, showing that this metal gives results not dissimilar to nickel steel, that is, the elastic limit and the breaking load are raised. The great expense of this metal is, of course, a bar to its use on a considerable scale.

The electrical resistance as determined by Professor Barrett, F. R. S., of which this is probably the first public reference in a metallurgical journal, was as follows:

| | Mark | Percentage Composition | | | | | Electrical Conductivity | | Specific Resistance |
|---|---|---|---|---|---|---|---|---|---|
| | | Fe | C | Mn | Co | Si | Iron =100 | Copper =100 | |
| Cobalt Steel | 1209C | 96.31 | 0.25 | 1.00 | 1.80 | 0.64 | 44.1 | 7.4 | 23.2 |
| | 1209F | 90.88 | 0.52 | 0.80 | 7.00 | 0.80 | 33.3 | 5.6 | 30.7 |

It is interesting to note the above results, as iron-nickel alloys of similar percentages showed almost the same specific resistance. For example, in the writer's specimen, 1287 D, described in his paper on "Alloys of Iron and Nickel," in which the nickel was 1.92 per cent, and the carbon 0.14 per cent, the specific resistance in microhms was 21.55 in the unannealed, and 20.44 in the annealed condition.

The original series of iron-cobalt alloys was made by the writer in May, 1891, and these results have not hitherto been made public. They therefore appear for the first time in this Journal.

The cobalt used was obtained from Messrs. Johnson Matthey & Co., and cost $6.50 per pound. The silicon present is somewhat high, but was added intentionally except in specimen D, where, through an error, the percentage was made too high, but this is nevertheless interesting as the tensile tests clearly show its influence upon the results.

The percentage of sulphur is high, this being partly due to its presence in the cobalt alloy added to the steel.

The following table shows the various results.

### TABLE I

| | | Analysis | | | | | | Estimated percentage of Cobalt |
|---|---|---|---|---|---|---|---|---|
| | | C | Si | S | P | Mn | Co | |
| 1209 | A | 0.20 | 0.64 | 0.10 | 0.06 | 0.80 | —– | nil |
| " | B | 0.16 | 0.61 | 0.10 | 0.07 | 1.04 | 0.53 | 0.50 |
| " . | C | 0.25 | 0.64 | 0.11 | 0.07 | 1.04 | 1.80 | 2.00 |
| " | D | 0.38 | 1.21 | 0.14 | 0.07 | 0.65 | 2.50 | 3.00 |
| " | E | 0.55 | 0.69 | 0.11 | 0.06 | 0.79 | 4.46 | 6.00 |
| " | F | 0.52 | c.75 | 0.14 | 0.06 | 0.79 | 6.91 | 9.00 |

*Tests on Forged Cobalt Steel Cut from Bars 1¼″ Dia.*

| | | Unannealed Test Bars Load in tons per sq. in. | | | | | Annealed Test Bars Load in tons per sq. in. | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Elastic Limit | Breaking Load | Elonga-tion | Reduction of Area | Fracture | Elastic Limit | Breaking Load | Elonga-tion | Reduction of Area | Fracture |
| | | Tons | Tons | Per Cent | Per Cent | | Tons | Tons | Per Cent | Per Cent | |
| 1209 | A | 27 | 37 | 24 | 28 | { Light granular { fibrous | 20 | 31 | 35 | 46 | { Fine dark { granular |
| " | B | 27 | 38 | 29 | 43 | { Very light { granular silky { fracture | 22 | 31 | 34 | 47 | { Dark granular { with slight traces { of fine crystalline |
| " | C | 25 | 41 | 19 | 24 | { Light granular { silky fracture | 23 | 35 | 29 | 39 | { Dark granular { 50% fine crystal-{ line |
| " | D | 38 | 52 | 15 | 15 | { Very fine, dark { crystalline | 27 | 43 | 14 | 24 | Fine crystalline |
| " | E | 37 | 57 | 15. | 17 | { Very fine crystal-{ line | 25 | 46 | 19 | 22 | { Fine dark { crystalline |
| " | F | * | 55 | 14 | 13 | do | 30 | 44 | 22 | 25 | { Very fine { crystalline |

* No set at 25, 30, 35.

Each specimen was tested on a length of 2″ × .7979 dia.

The results of the tests show that the cobalt, like nickel, considerably increased the elastic limit and the breaking load.

Specimen " A " contains no cobalt, and is, therefore, a comparison with specimens " B " to " F ", which all contain cobalt.

*Alloys of Iron and Copper.* — The alloys of copper with iron are of considerable interest, specially from the fact that its presence in certain percentages raises the elastic limit considerably. Its use, however, in percentages sufficient to show a marked influence upon the alloy, is rendered of somewhat doubtful value from the fact that for forged work it causes considerable red shortness. A number of tests showing this influence are given in the accompanying Tables Nos. II and III and diagrams in Figs. 2 and 3 regarding its tensile strength, also as to its effect upon the elastic limit.

*Alloys of Iron and Titanium.* — The effect of the element titanium upon iron has not so far been determined with accuracy. Apparently it acts in some way like aluminium in absorbing gases, but the product appears to be of no special value, as after exceeding about 0.3 per cent the physical qualities of the metal are unfavorably affected. If it is present in small quantities it seems to have the effect of somewhat raising the elastic limit.

*Alloys of Iron and Molybdenum.* — The writer has made tests with molybdenum, and finds its effect somewhat similar to tungsten, though, for example, like manganese as compared with nickel, its important confrère in the same grade, a much lower percentage than of tungsten is necessary to produce the same effect.

*Alloys of Iron and Vanadium.* — The element vanadium has in the past been so expensive that its value would have to be very great to render the benefit obtained by its addition other than somewhat problematic. It is claimed that this metal greatly increases the elastic limit, but it is doubtful whether this is so, except in the presence of carbon, that is, its action is not unlike that of chromium, though lesser percentages are stated to give the same effect as the latter metal. In view of its even now very high first cost, why use so expensive an element when a much cheaper one, such as chromium, appears to answer the same purpose? The writer has produced steel containing nickel and chromium that gave higher elastic limit and tenacity, also comparatively higher elongation, than shown by results obtained from alloys of iron with vanadium.

*Tensile Strength in tons per sq. inch.*

*Elastic Limit in tons per sq. inch.*

*Elongation, per cent in two inches.*
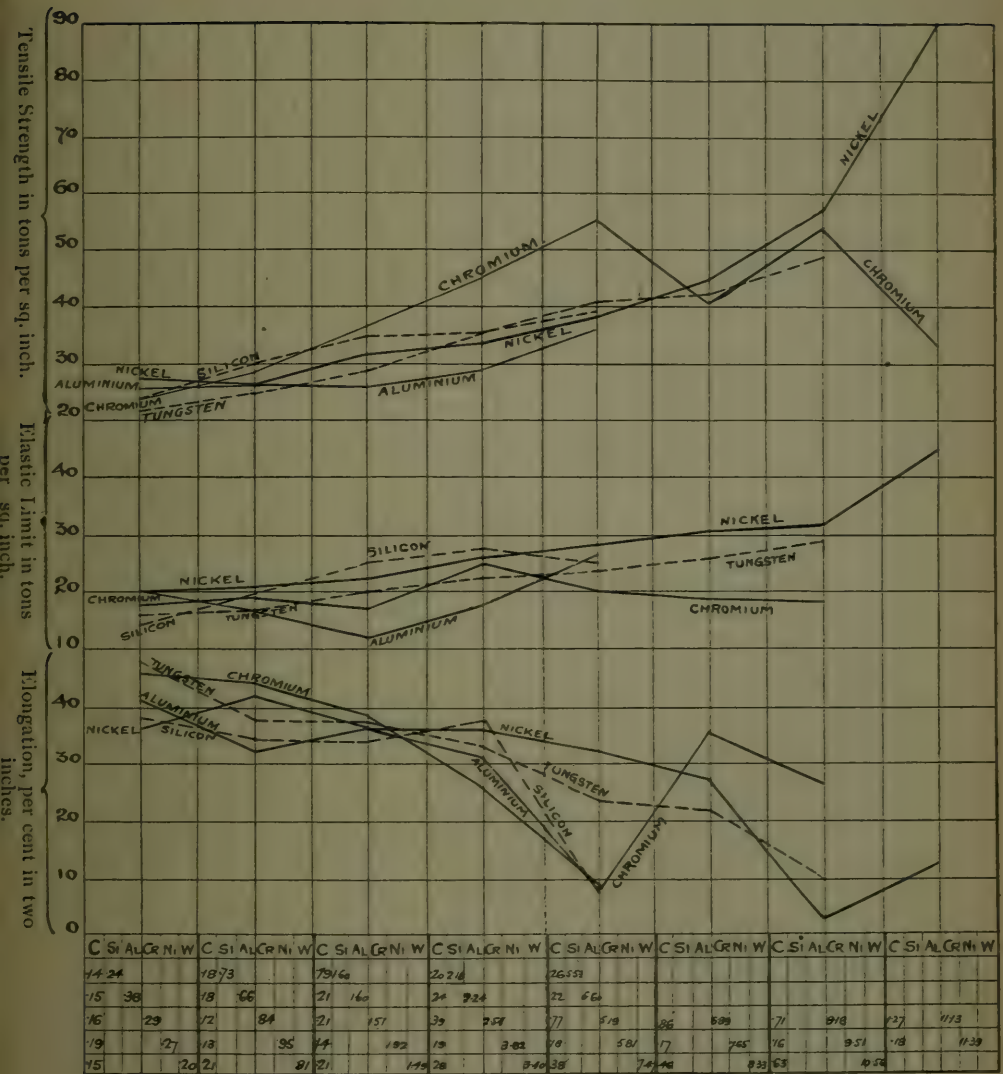
Fig. 2. Comparison of Tensile Strength, Elastic Limit and Elongation of Forged and Annealed Silicon, Aluminium, Chromium, Nickel and Tungsten-Iron Alloys. (Plotted from Table 2.)

A general comparison of the elastic limit, breaking load, elongation, reduction of area, and bending tests of the forged annealed material is given in Table II, and a comparison of compression tests on forged unannealed material in Table III, of iron alloyed with silicon, aluminium, chromium, nickel, tungsten and copper.

The results in Tables II and III are plotted on the diagrams shown in Figs. 2 and 3.

TABLE II. — *Comparison Table of Elastic Limit, Breaking Load, Elongation, Reduction of Area, and Bending Tests of Forged Silicon, Aluminium, Chromium, Nickel, and Tungsten-Iron Alloys, all the material having been annealed. To these are added comparisons of Copper Alloys. These results are plotted on Fig. 2.*

| Steel | C | Si | Al | Cr | Ni | W | Limit of Elasticity in Tons per sq. in. | Breaking Load in Tons per sq. in. | Elongation, per cent on Two Inches | Reduction of Area per cent | Breaking Test of Annealed Forged Sample |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Per cent | Per cent | Per cent | Per cent | Per cent | Per cent | | | | | |
| Silicon     A | 0.14 | 0.24 | — | — | — | — | 15.17 | 25.00 | 37.55 | 60.74 | Double |
| Aluminium A | 0.15 | — | 0.38 | — | — | — | 20.00 | 26.00 | 40.35 | 60.74 | " |
| Chromium B | 0.16 | — | — | 0.29 | — | — | 17.00 | 25.00 | 45.55 | 65.90 | " |
| Nickel     A | 0.19 | — | — | — | 0.27 | — | 20.00 | 28.00 | 37.05 | 52.14 | " |
| Tungsten   B | 0.15 | — | — | — | — | 0.20 | 16.50 | 22.00 | 46.30 | 66.48 | " |
| Copper 1240/0 | 0.19 | — | — | — | — | Cu 0.40 | 24.00 | 43.00 | 21.45 | 28.22 | " |
| Silicon     B | 0.18 | 0.73 | — | — | — | — | 19.00 | 29.50 | 34.02 | 52.66 | Double |
| Aluminium C | 0.18 | ?— | 0.66 | — | — | — | 18.00 | 27.00 | 33.00 | 52.14 | " |
| Chromium E | 0.12 | — | — | 0.84 | — | — | 19.00 | 28.00 | 42.50 | 61.20 | " |
| Nickel     C | 0.13 | — | — | — | 0.95 | — | 20.50 | 27.00 | 41.75 | 63.36 | " |
| Tungsten   E | 0.21 | — | — | — | — | 0.81 | 18.00 | 26.25 | 37.60 | 53.26 | " |
| Copper 1240/1 | 0.25 | — | — | — | — | Cu 1.39 | 32.00 | 43.00 | 31.41 | 50.92 | " |
| Silicon     C | 0.19 | 1.60 | — | — | — | — | 25.00 | 33.00 | 35.10 | 54.52 | Double |
| Aluminium F | 0.21 | — | 1.60 | — | — | — | 13.00 | 26.00 | 36.35 | 67.00 | " |
| Chromium G | 0.21 | — | — | 1.51 | — | — | 19.00 | 33.50 | 38.07 | 55.88 | " |
| Nickel     D | 0.14 | — | — | — | 1.92 | — | 22.00 | 31.00 | 36.26 | 53.70 | " |
| Tungsten   G | 0.21 | — | — | — | — | 1.49 | 19.50 | 28.50 | 36.90 | 54.88 | " |
| Silicon     D | 0.20 | 2.18 | — | — | — | — | 25.50 | 34.00 | 36.50 | 59.90 | Double |
| Aluminium H | 0.24 | — | 2.24 | — | — | — | 18.50 | 28.50 | 33.00 | 48.62 | " |
| Chromium H | 0.39 | — | — | 2.54 | — | — | 24.50 | 44.00 | 24.50 | 33.84 | " |
| Nickel     E | 0.19 | — | — | — | 3.82 | — | 25.00 | 33.00 | 35.85 | 55.86 | " |
| Tungsten   A | 0.28 | — | — | — | — | 3.40 | 23.00 | 34.00 | 33.90 | 53.02 | " |
| Copper   A/2 | 0.23 | — | — | — | — | Cu 2.72 | 23.00 | 33.50 | 29.95 | 45.14 | " |
| Silicon     H | 0.26 | 5.53 | — | — | — | — | 25.00 | 25.00 | 0.37 | 2.00 | { Would not bend . |
| Aluminium I | 0.22 | — | 5.60 | — | — | — | 27.00 | 36.00 | 6.45 | 6.16 | 16° brok'n |
| Chromium J | 0.77 | — | — | 5.19 | — | — | 20.00 | 55.00 | 8.20 | 6.88 | Double* |
| Nickel     F | 0.18 | — | — | — | 5.81 | — | 28.50 | 37.00 | 33.15 | 51.62 | " |
| Tungsten   I | 0.38 | — | — | — | — | 7.47 | 24.00 | 40.00 | 25.65 | 38.46 | " |
| Copper     B | 0.16 | — | — | — | — | Cu 4.40 | Would not forge | | | | " |

* Carbon in chrome sample too high to make direct comparison.

Fig. 3. Comparison of Compression Tests on Forged Unannealed Silicon, Aluminium, Chromium, Nickel and Tungsten-Iron Alloys, Reduction in length, per cent, produced by a compression load of 100 tons per sq. inch. (Plotted from Table 3.)
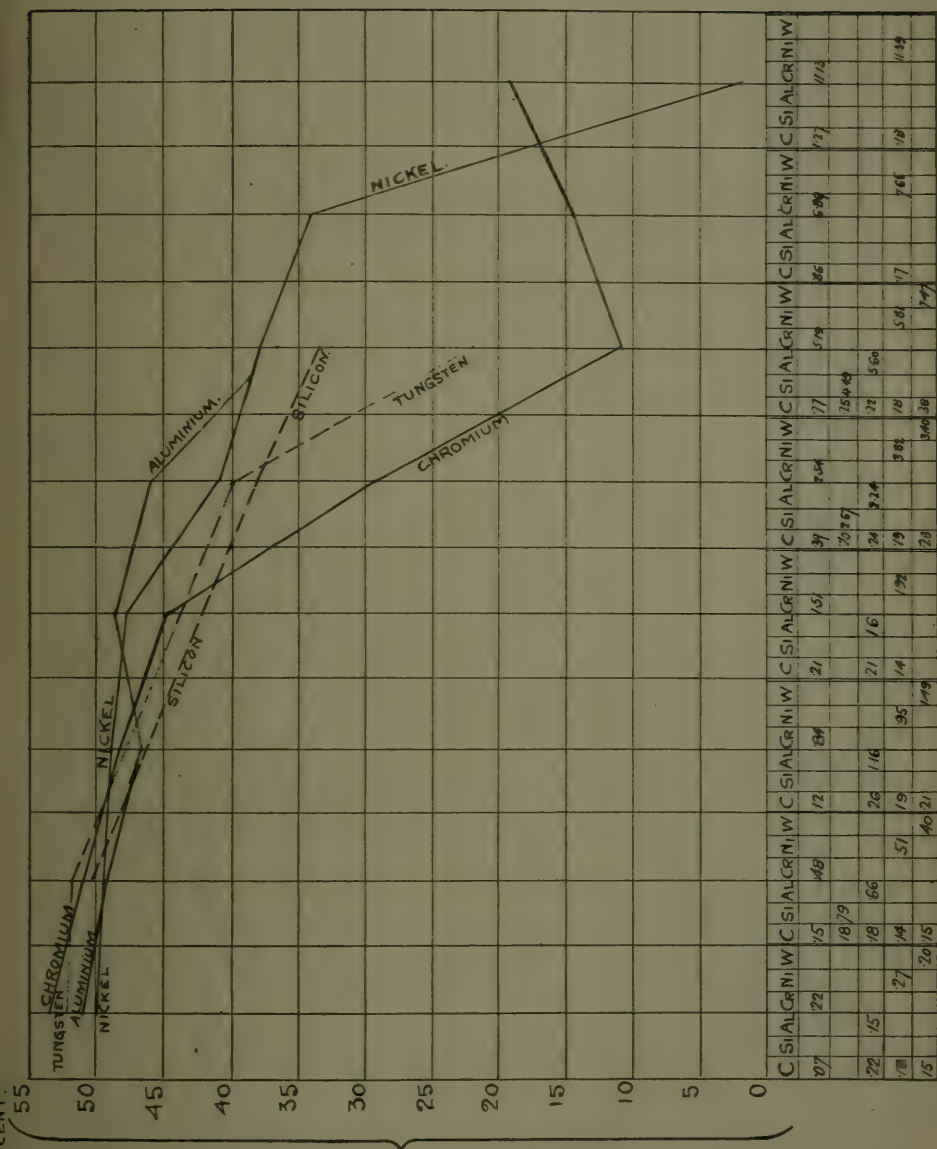
As it does not seem out of place here, in reference to research work on iron alloys, the writer would like to quote a recent important statement by that well-known scientist M. Osmond, for

TABLE III. — *Comparison of Compression Tests on Forged Unannealed Silicon, Aluminium, Chromium, Nickel, and Tungsten-Iron Alloys. These results are plotted in Fig. 3.*

| Steel | Specimen Mark | Analysis | | | | | | Tons per Square Inch | |
|---|---|---|---|---|---|---|---|---|---|
| | | C | Si | Al | Cr | Ni | W | Yield or Set Point | Shortening Produced by a Load of 100 Tons |
| | | Per Cent | Per Cent | Per Cent | Per Cent | Per Cent | Per Cent | Tons | Per Cent |
| Silicon | — | — | — | — | — | — | — | — | — |
| Aluminium | — | 0.22 | — | 0.15 | — | — | — | — | 51 |
| Chromium | A | 0.07 | — | — | 0.22 | — | — | — | 53½ |
| Nickel | A | 0.19 | — | — | — | 0.27 | — | 22 | 50 |
| Tungsten | B | 0.15 | — | — | — | — | 0.20 | 30 | 52 |
| Silicon | B | 0.18 | 0.79 | — | — | — | — | — | 50 |
| Aluminium | C | 0.18 | — | 0.66 | — | — | — | — | 49 |
| Chromium | C | 0.15 | — | — | 0.48 | — | — | — | 50½ |
| Nickel | B | 0.14 | — | — | — | 0.51 | — | 22 | 50 |
| Tungsten | C | 0.15 | — | — | — | — | 0.40 | 30 | 51 |
| Silicon | — | — | — | — | — | — | — | — | — |
| Aluminium | E | 0.26 | — | 1.16 | — | — | — | — | 47 |
| Chromium | E | 0.12 | — | — | 0.84 | — | — | — | 48 |
| Nickel | C | 0.13 | — | — | — | 0.95 | — | 20 | 49 |
| Tungsten | G | 0.21 | — | — | — | — | 1.49 | 30 | 48 |
| Silicon | — | — | — | — | — | — | — | — | — |
| Aluminium | F | 0.21 | — | 1.60 | — | — | — | — | 48 |
| Chromium | G | 0.21 | — | — | 1.51 | — | — | — | 44½ |
| Nickel | D | 0.14 | — | — | — | 1.92 | — | 27 | 47 |
| Silicon | E | 0.20 | 2.67 | — | — | — | — | — | 38 |
| Aluminium | H | 0.24 | — | 2.24 | — | — | — | — | 45½ |
| Chromium | H | 0.39 | — | — | 2.54 | — | — | — | 29½ |
| Nickel | E | 0.19 | — | — | — | 3.82 | — | 28½ | 41 |
| Tungsten | H | 0.28 | — | — | — | — | 3.40 | 40 | 40 |
| Silicon | G | 0.25 | 4.49 | — | — | — | — | — | 32 |
| Aluminium | I | 0.22 | — | 5.60 | — | — | — | — | 36½ |
| Chromium | J | 0.77 | — | — | 5.19 | — | — | — | 11 |
| Nickel | F | 0.18 | — | — | — | 5.81 | — | 40 | 38 |
| Tungsten | I | 0.38 | — | — | — | — | 7.47 | 40 | 21 |
| Silicon | — | — | — | — | — | — | — | — | — |
| Aluminium | — | — | — | — | — | — | — | — | — |
| Chromium | K | 0.86 | — | — | 6.89 | — | — | — | 14½ |
| Nickel | G | 0.17 | — | — | — | 7.65 | — | 40 | 34 |
| Tungsten | L | 0.76 | — | — | — | — | 15.65 | 50 | 10 |
| Silicon | — | — | — | — | — | — | — | — | — |
| Aluminium | — | — | — | — | — | — | — | — | — |
| Chromium | M | 1.27 | — | — | 11.13 | — | — | — | 19 |
| Nickel | I | 0.18 | — | — | — | 11.39 | — | 100 | 1 |
| Tungsten | M | 0.78 | — | — | — | — | 16.18 | 70 | ▪ |

whom, deservedly, the metallurgical world has the highest respect. M. Osmond commences by referring to the Hadfield paper on " Alloys of Iron and Tungsten," and remarks " that it formed a continuation of the series of former memoirs conceived and carried out in the same spirit. It would therefore appear reasonable to review the general results, which, directly or indirectly, were becoming more and more apparent, of these successive monographs by Mr. Hadfield.

" In the first place, a mass of new ideas had been gained upon facts little known in the history of metallurgy. Mr. Hadfield being in a high degree imbued with respect for his predecessors, and with a sense of appreciation of their labors. The historic portion, which demanded patient and exhaustive research among the archives of the past, was not always appraised at its true value. Nevertheless, a research of this nature had, independently of its moral bearing, a practical value in sparing the investigator the trouble of recommencing work already done and from attempting what had been found useless. It also served to bring to the minds of present workers that they were the actual agents of an uninterrupted evolution, and there were few men who had exercised an influence upon the progress of this evolution comparable to that which had been brought to bear by Mr. Hadfield.

" The series of his alloys had been prepared with a degree of technical skill which upset many falsely conceived ideas, resulting from imperfect preparation or from faulty manipulation. His method was a truly scientific one, by means of which all the independent variables which could be disposed of were eliminated. With the materials for investigation thus prepared, which for a long time had been unrivaled in purity, the results obtained were at once clear, coherent, and definite. Moreover, Mr. Hadfield had not used this wealth of material merely for his own personal advantage, but with never-failing generosity, of which the writer had many times availed himself, he had placed it at the disposal of those investigators who were desirous of subjecting it to their methods and of using it for their researches. Further, the useful results had rapidly gone on increasing, and from the accumulation of these the general laws had been evolved which formed the main object of all research. One fact, foreshadowed by Mr. Hadfield since his earliest beginning, was clearly evident, namely, that all the useful foreign substances added to iron had the effect of essen-

tially modifying the iron itself and they might be substituted for one another, in equivalent proportions, not, it is true, without modifying to some extent the secondary properties, but without altering abruptly the essential characteristics of the type; that was to say, and this was the chief point, that there were metallurgical equivalents for substances which, though widely differing numerically from the chemical equivalents, were nevertheless qualitatively analogous.

"The three principal modifiers of iron were hardening carbon, manganese, and nickel. Their metallurgical equivalents were the respective proportions of them which would lower by the same amount the points of transformation upon the scale of temperatures. Mr. Guillet, who was even now at work to determine the numerical values of these equivalents with greater precision than had yet been attempted, had found that 1.65 parts of hardening carbon, or more exactly, 1.65 parts of total carbon containing the maximum amount of hardening carbon was equivalent to 12 parts of manganese and to 29 of nickel. Chromium and tungsten, and probably also molybdenum and vanadium (the writer had, however, only few papers relating to the two latter) were not direct modifiers, but had as their object the maintenance of the carbon in the state of hardening carbon under conditions of thermal treatment in which the carbon alone would separate into the state of free carbide with little activity. Their reflex action upon the carbon was itself governed by a law of equivalence.

"Now according as, with a given addition of one or several bodies, and under fixed conditions of heating and cooling, the transformations were maintained above 400° C. approximately, or were lowered so as to occur between 400° C. and the ordinary temperature, or were pushed down to a point below the ordinary temperature, there would be produced three essential types of iron, not taking account of the intermediary types which connected them. These three types would correspond respectively to the complete transformations, to the incomplete transformations, and to no transformations at all. The first type is soft iron.

"The second corresponds to hard quenched steel, and its kindred substances.

"The third corresponds to non-magnetic steels, which are subject to deformation and at the same time are very difficult to work.

" The two first had been familiar since the dawn of time, the third was due to the discoveries of Mr. Hadfield.

" Considered from this point of view the discovery of manganese steel no longer appeared merely as a discovery of a new alloy, curious and yet useful, but it ranked as a discovery equal in importance only to that of the effect of quenching, in the history of the metallurgy of iron, the only one of the same order which it had been reserved for our age to make.

" It seemed to the writer that the truth of this had not been perceived, certainly not at Sheffield, probably because steels whose transformations were nil, could not be worked cold in the form of manganese steel, and were too expensive in the form of nickel steel. But there was nothing to prove that these difficulties were so insuperable as to prevent such metals forever from being adapted to the extensive applications for which their properties appeared to destine them."

The writer in reply would say that the very important point mentioned by M. Osmond regarding the relative effect or " equivalency " of manganese and nickel should be carefully borne in mind by those experimenting upon iron alloys.

He need hardly say what great satisfaction he derived from M. Osmond's comments on the efforts involved in the preparation of this laborious research. To have his efforts regarding the historical side of the research appreciated was specially gratifying, as few realize the labor involved.

M. Osmond rightly points out that the Metallurgist is an agent in an uninterrupted evolution, but how quickly has this taken place! The writer in 1888, or only 15 years ago, presented his paper on " Alloys of Iron and Manganese," which was the first systematic research work on alloys of iron with other elements. In this comparatively short interval of time the progress has been enormous, this being largely brought about by the mutual working together of not only the metallurgist who produced, but by those who prepared the alloys, and finally the scientist who has carried out the research work.

M. Osmond's statement regarding many important metallurgical questions which have arisen out of the invention by the writer of manganese steel are not in any way over-estimated. He is not a little gratified that such an authority as M. Osmond con-

siders that not merely was the invention of this new alloy impor-
tant from a commercial and practical point of view, but that it
ranked in the history of the metallurgy of iron as a discovery
equal in importance only to that of the effect of quenching. Whilst
tungsten-iron alloys do not present any startling future, there is
no doubt a considerable field for further valuable research as
to their practical application.

Regarding M. Osmond's communication, the writer would
once more express to M. Osmond how deeply he has valued the
continuous sympathy and interest shown by this great French
scientist to whom the metallurgical world owes such a debt of
gratitude for the invaluable work he has done by his observations
on the thermal treatment of alloys of iron with other elements,
and their physical qualities. The unswerving and helpful con-
sideration given to any new problem arising from time to time
presented to M. Osmond by the writer has often given courage in
facing difficulties which at times seem insurmountable. The
benefits that will occur to the workers in this century from M.
Osmond's researches can hardly be calculated.

In conclusion, the examination of the properties of iron
alloyed with other elements is being continued with increasing
vigor, and valuable results, both from the immediate practical as
well as the scientific point of view, are accruing to the world from
the labors of the Metallurgist. Nowadays we do not hunt for
the Philosopher's Stone, but verily the Metallurgist has produced
" Transmutations " that even ten years ago would not have been
thought possible. The writer has produced alloys with tensile
strengths all the way from 18 tons up to 110 tons per square inch,
and with elongations from nil to 70 per cent. But, singular as
it may seem, notwithstanding the important part played by all
these new iron alloys, carbon still maintains its premier position
in determining the practical value of the various products, in other
words, there are few, if any, iron alloys in which, apart from the
effect produced by the special element added, the presence of
carbon is also unnecessary, therefore, whatever the theory believed
in by each reader of this article, that is, whether he is a Carbonist
or Allotropist, it has to be admitted that carbon alone is the pre-
dominant factor in determining the utility of the alloy. The
writer is not stating this in any controversial spirit, as, of course,
the Allotropist, whilst admitting the importance of carbon, claims

its action is different to that believed in by the Carbonist, but the fact remains that carbon must be present to render the alloy of practical value.

Finally, may it not be claimed that the world is more than ever indebted to that indefatigable body of men, the Metallurgists, who labor on, year by year, through difficulties often apparently insurmountable, to improve and perfect the qualities of iron for the general benefit of mankind.

As this article is for the first number of the enlarged *Metallographist* of America, the writer wishes God Speed to the members of his craft in their work in that Great Republic, where he has always received so much personal kindness and courtesy. He offers every good wish for continued success to the Editors in the continuation of their efforts to improve and enlarge the stores of information on metallurgical matters.

# BY-PRODUCT OVEN GAS AND TAR AS FUELS FOR THE OPEN-HEARTH FURNACE

By DAVID BAKER

General Manager, Dominion Iron and Steel Co., Sydney, Canada

NOW that the installation of retort ovens with the recovery of by-products is becoming common practice on this side of the Atlantic, among iron and steel manufacturers, the experience at the works of the Dominion Iron & Steel Company, Sydney, Cape Breton, may be found profitable to others confronted with the same problem.

Originally the coke ovens at these works consisted of a plant of 400 Otto-Hoffmann retort ovens arranged for the recovery of the principal by-products — gas, tar, and ammonia. The coal used, which comes from the Phalen seam of the Dominion Coal Company, contains 33 per cent of volatile combustible matter, and yields 5,000 cu. ft. of surplus gas per net ton of coal. The engineers constructing the ovens calculated this surplus to be 10,000,000 cu. ft. per 24 hours, estimating the thermal value of this gas to be 75 per cent of natural gas used in Pittsburgh at that time. It was considered that this gas surplus would provide for the manufacture of 900 tons of rolled steel per day.

To provide against the usual disappointments consequent upon estimates made in a new field of Metallurgy, the Blooming Mill was equipped with gas producers and three of the open hearth furnaces as well, the whole plant consisting of 10 Campbell tilting furnaces lined for the basic process and rated at 50 tons capacity. The gas was introduced into the furnaces without regeneration, the same as is customary with natural gas, through 2 six inch pipes entering each side of the ports of the furnace (see Fig. 1). No attempt was made at regeneration, on account of the deposition of carbon, which has been found in the use of natural gas under the same conditions to fill the checkers up very rapidly.

The gas producers not being completed when everything else about the open hearth plant was ready for a start, it was decided to make the first heat with coke oven gas as fuel. The trial showed at once that the furnaces could not be operated commercially with that fuel alone.

A test of the gas in the calorimeter showed 550 B.T.U., while the analysis of the gas was as follows:

COKE GAS

| | | |
|---|---|---|
| $CO_2$ | 3.3 | per cent |
| Illum | 3.8 | " |
| O | .5 | " |
| CO | 5.4 | " |
| $CH_4$ | 31.2 | " |
| H | 43.3 | " |
| N | 12.5 | " |

At this stage the construction of more gas producers was immediately commenced, but in the interval, it was important to obtain some means of increasing the temperature of the furnaces while using the coke oven gas.

At this time there was stored on the plant over a million gallons of tar, the market for which was poor, and it was decided to try to burn this tar as an auxiliary to the coke oven gas.

After a number of experiments the burner shown in Fig. 2, was adopted as giving the best results. In the burner the steam is admitted at A, and the tar at B. The valve in the pipe leading to A was drilled so that the steam could not be entirely shut off,

Fig.
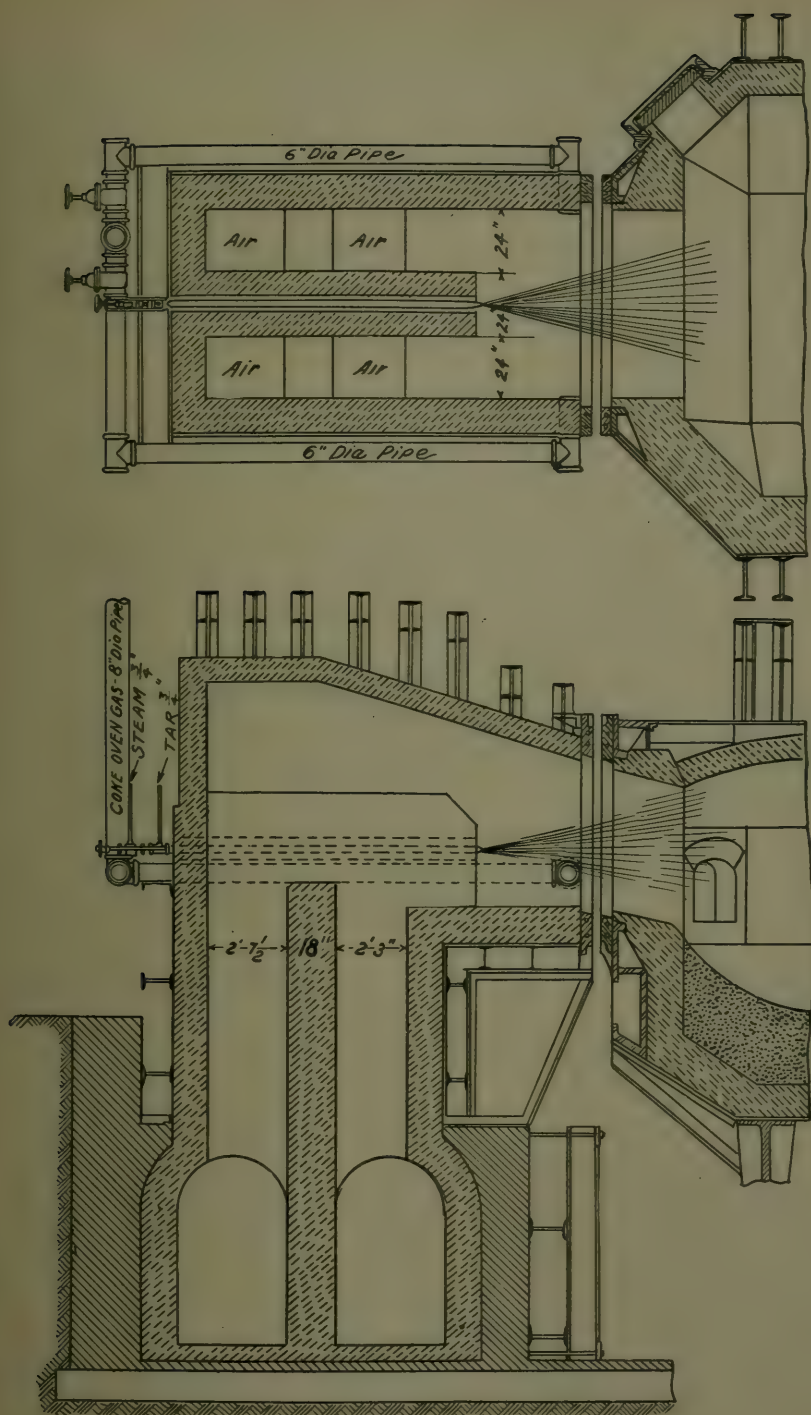
a ⅜″ hole in the seat being found sufficient to keep the nozzle of
the burner from melting off when the furnace was reversed.

With this burner there was no difficulty in maintaining all
the temperature desired in the furnace with coke oven gas, or with
tar alone.   Changes in temperature could be effected very quick-
ly, but it was necessary to be very watchful of the roof, for
frequently carbon would deposit on the nozzle diverting sharply
the intense flame to some point in the roof which would very
soon commence to flow.   In using the tar it was found necessary
to put steam coils in the receiving tank, and to deliver this into
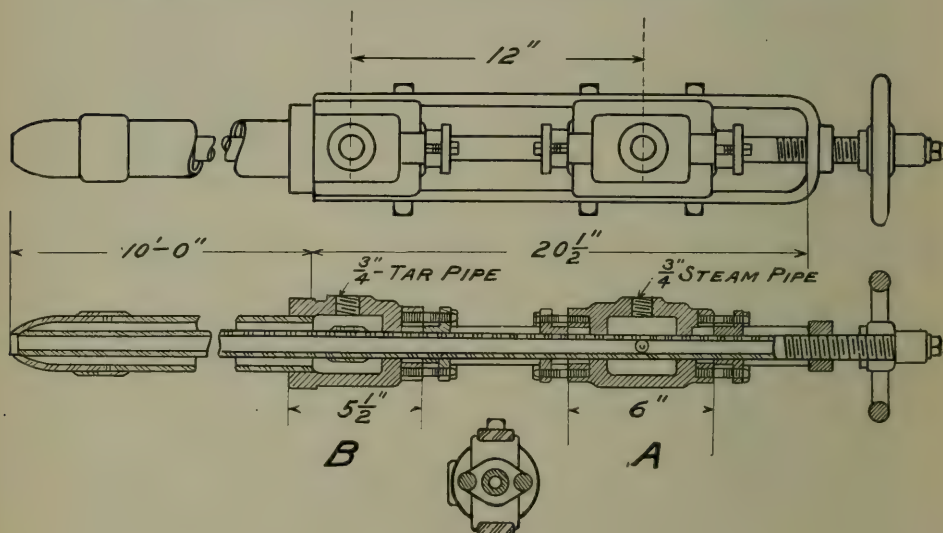


Fig. 1.

a heated tank about 50 ft. above the furnaces from whence it was
delivered into the furnaces through a steam heated main.   From
this experience some valuable information was obtained of the
advantages of tar as a fuel for the open hearth furnace, as well
as the efficiency compared with coke oven and producer gas.

In these furnaces the pig and ore process is used with quick
lime and Swedish iron ore.

The coal used contained on an average 2.10 per cent of sul-
phur, and the coke-oven gas 500 grains of sulphur per 100 cubic
feet.

Crushed raw coal was charged direct into the ovens, the

washer having been destroyed by fire. In the coking about 44 per cent of the total sulphur was volatilized.

The tar contained 0.25 per cent of sulphur.

The producer gas was of the following average analysis:

$CO_2$ .................... 6.2 per cent
O .................... 0.6 "
Illum. .................... 0.4 "
CO .................... 22.0 "
N .................... 64.8 "
H .................... 6.0 "

The results obtained in the manufacture of 22,000 tons of steel with coke oven gas, and tar in comparison with a like quantity of steel made with producer gas shows that in the manufacture of one ton of steel, the following amount of each kind of fuel was required:

{ 17,127 cu. ft. oven gas (550 B. T. U. per cu. ft.*)
   584.2 lbs. of tar (15,781 B. T. U. per lb., solid.*)
1,076 lbs. coal (12,500 B. T. U. per lb.*)

The tar used in these tests contained 13½ per cent of water, after deducting this and the heat required for the conversion of this water to steam gives 13,500 B. T. U. per lb.

As the coke oven gas was burned in the furnace with superheated air, the combustion may be considered to be complete, while the combustion of the tar was not complete, as was evidenced by the smoke which issued from the furnace openings.

One pound of tar has therefore the following equivalents:

1 lb. tar equals 24½ cu. ft. of coke gas, but by assuming that the coke oven gas and coal is burnt at full efficiency, the tar in the furnace gives only 51.1 per cent efficiency, or 1 lb. of tar in the furnace had the following efficiency:

1 lb. tar equals 12.52 cu. ft. coke gas.
1368 lbs. tar equals 17,127 cu. ft. coke gas, hence 1368+584, or 1952 lbs., or 166 imperial gals. of tar = 1076 lbs. coal.
142 gals. solid tar = 1076 lbs. coal.

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* Results obtained by Calorimetric test by Dominion Coal from the New England Coke and Gas Co., Everett, Mass.

The sulphur introduced into the process was, therefore, as follows:

1,076 lbs. coal contain...................22.596 lbs. sulphur
17,127 cu. ft. coke gas, and 584 lbs. tar contain 13,693 lbs. sulphur

*Changing Gas to Tar.* —

1,852 lbs. tar $=$ 4.880 lbs. sulphur.

*Changing Tar to Coke Oven Gas.* —

24,440 cu. ft. coke gas $=$ 17.457 lbs. sulphur.

By this it is clear that in the use of coke oven gas and tar 39.4 per cent less sulphur was introduced into the process than when producer gas was used alone, and if tar alone were to be used, 78.4 per cent less sulphur would be introduced.

These conclusions were borne out by the operations, for in the furnaces using coke oven gas and tar, the sulphur in the charge was very easily controlled, which was not always the case in those operated by producer gas.

From the point of economy the use of tar does not commend itself at present market price for this product. But it is conceivable with the increase in the number of plants of by-product ovens now being constructed, that the price of tar may be low enough to make its use an economy, as well as a convenience, particularly should it be so introduced into the furnace as to secure a better combustion.

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## A PROBLEM IN THE METALLURGY OF CAST IRON

By Dr. RICHARD MOLDENKE
Secretary American Foundrymen's Association

CONSIDERABLE attention has of late been directed to the study of cast iron from the metallurgical standpoint, and we come across problems herein which are far more complex than those met with in the closely related steel casting. It is only in the physical manipulation of the latter in the foundry that special attention must be paid, the higher temperature, and absence of mechanically mixed graphite limiting appliances, methods, and materials to a very few high class steel castings, whereas ordinary iron castings are produced under a variety of conditions.

The chemical properties of cast iron are such that failure to meet specific requirements may occur at any time. We have to deal with comparatively high amounts of impurities, any one of which

in similar quantity would unfit a steel for service, as a regular feature of the industry. Even the carbon present may be in the shape of graphite, mechanically mixed, temper carbon, one of several forms of combined carbon, or all of them together.

The art of founding has now been studied from its metallurgical side sufficiently to allow us to make a mixture with the reasonable assurance that the requirements will be met (the molding conditions, as we may term them, being presupposedly correct) barring only two factors. These two factors are the absorption of sulphur from the fuel, and the retention of the oxide originally in the metal charged or else introduced subsequently as part of the melting process.

On the sulphur question this much can be said: By the purchase of irons and coke comparatively low in sulphur much of this trouble can be avoided, indeed even with sulphur present in considerable quantities in the coke, the use of sufficient fuel to make very hot iron drives off sulphur before it can combine with the melted metal. Then again by adding some ferro-manganese to the ladle, or better still using a high manganese pig in the mixture, some of the sulphur can be slagged off. Possibly, however, the addition of a manganese ore with the flux promises the best results, the recent European experiments along this line justifying a closer study of the method. Here also it must be remembered that only the plentiful use of fuel will give favorable conditions to effect a removal of the sulphur.

The greatest and perhaps least realized difficulty the foundry industry has to contend with, is the presence of dissolved oxide of iron in the pig and scrap used for the production of castings requiring exceptional ability to withstand severe and rough service. Take for instance the chilled roll, with the enormous strains, both from the metal pressed and the internal heat variables, to be overcome without injury; the heavy rough and intermittent service required of it, and the damage and delay when it breaks. Again, look at the production of the roll casting in the first place. Enormous molecular tension exists as the mass slowly cools. It is little wonder that many rolls crack before they are cold, and still more of them must be thrown out for defects laid bare upon turning them up.

In this industry we note that the founder takes the natural method of overcoming these difficulties by buying only the very best of irons, which does not mean the purest by any means, but

those irons which his experience has shown him to be able to resist
the casting strains successfully, as against others with the same
composition which do not. We find the same thing holding true for
the car wheel, the malleable casting, and a number of other
branches of the foundry industry where physical strength must be
combined with a given composition.

Now what is the reason that the crystals of one iron adhere
to each other so much more tenaciously than those of another of
exactly the same composition and made under the same heat condi-
tions? A wide experience with the open hearth and the reverbera-
tory furnace for cast iron leads me to conclude that this is due only
to the greater or less freedom of the iron from dissolved oxide.
Even the most unenlightened founder when judging the probable
strength of an iron from its freshly fractured surface will pass his
hand over it to note whether the particles have been roughly torn
apart or whether they have simply separated from each other along
crystal planes. In the former case the iron must have been tough
and hard to separate, and in the latter it was weak and unable to
withstand shock.

It is for this reason that I proposed some time ago to test pig
iron by remelting under standard conditions, casting standard test
bars, and subjecting these to physical tests, a given composition
thus showing the quality of the iron tested when compared with
others of the same composition for just such important work as
rolls, car wheels, malleables, gun metal, and furnace or cupola iron
in general which must be up to and if possible beyond the high
water mark for cast iron. The time, however, does not seem ripe
for this, and so we must turn to other methods of overcoming this
difficulty which is more marked in the low silicon irons than in
those used for the softer castings.

Judging from steel practice we would at once turn to ferro-man-
ganese for the removal of oxide from the bath. Professor Ledebur
showed the effect of this addition very nicely by determinations of
the oxygen present before the addition of the metal, and right after
it. This illustrated the entire removal effected. Then there was
a gradual accumulation of more oxygen in spite of the manganese
present, followed with a second addition of ferro-manganese.
When the steel was tapped its freedom from dissolved oxide was
shown. Now this looks very nice for steel, but unfortunately cast
iron when in the molten state is not so hot, so that the reactions

with manganese do not take place so far as the oxygen is concerned, and therefore some other method must be used.

Aluminium is the next element which appeals to us. In the high silicon irons there is no objection to its use, in fact it immediately absorbs the gases present and quiets the metal if it should be troubled. But for the low silicon irons aluminium cannot be used, unless in the smallest quantities, as it promotes the formation of graphite, which is fatal to much of the work for which these irons are used.

The last candidate for favor is titanium, in an iron alloy. From experiments made by Mr. Rossi in my foundry, I am inclined to think very favorably of its use as a purifier of the metal from just this oxidation, at least to a considerable extent. The addition of some 0.2 per cent of titanium to the metal, all of which was oxidized away, left the metal about 20 per cent stronger, yet with no change in the composition as a result of this addition. This would seem to indicate something of value. I rather think that other elements will be found to act similarly, and suggest that experiments be conducted to this end.

If we can ever arrive at a method which will correct the injurious effects of poor blast-furnace practice, poor melting in the foundry, in fact restore a bath of iron to its purity, if this word may be used, so that when cast, the metal of a stated composition may have a corresponding strength, as is the case in open-hearth steel, where the making of given carbon steels for required physical tests is a matter of daily practice — if we ever reach that point, a gigantic stride will have been made in the metallurgy of cast iron.

I therefore throw out this suggestion to our investigators, asking them to work along the lines indicated, to give the foundry industry the means of saving metal and thus working closer to the requirements of the age in conserving the resources of iron industry.

## SORBITIC STEEL RAILS *

### By J. E. STEAD, F. R. S., and ARTHUR W. RICHARDS

I N every branch of human life and in all sciences it has been the habit to give names to properties, substances, effects, and things, providing they have some distinct character peculiarly their own. Such a course is most commendable, otherwise it would be necessary invariably to employ long and descriptive sentences when either writing or speaking about them.

In the nomenclature of chemists and physicists names conveying some idea of the character or composition of the substance are usually chosen. Thus we have the name " chlorine," given to a greenish gas ; " bromine," to an evil-smelling liquid ; " hydrogen," because water is produced on burning it ; and " radium," because of its peculiar radiations.

In mineralogy it is a common practice to give terms containing the name of the discoverer or place where it was discovered, or that of some one whom the discoverer wished to honor, to the termination of which the letters -ite are added. Thus we have Cliftenite, Labradorite, etc. Occasionally a mineral has been described by a term which contains some clue to the character of the first specimen discovered, but there are cases known in which such terms were not applicable to the same mineral or to varieties of it discovered later. Therefore they are distinctly misleading. Where a mineral or substance has a definite and constant composition and character which can be expressed by some existing term, it is certainly desirable to use the old rather than to coin a new one. There are, however, living to-day some prominent mineralogists who consider it expedient and safer not to give descriptive terms, and prefer arbitrary names.

In mineralogy, as in chemistry and other sciences, the person who makes a discovery is without exception allowed the right to give the name to the thing discovered, and it is rare that this right has been disputed.

With regard to sorbite, exception has been taken by some that it has not a sufficiently distinctive character to justify recognition of its individuality. It is pleaded that it is a transition condition of

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* Iron and Steel Institute Sept., 1903.

the carbide intermediate between the state in which it exists in hardened and annealed steels. As a matter of fact there is an agreement as to the description, but opinion differs as to its distinctive character. It was Osmond who first used the term,* and his remarks introduced below show the ground on which he justified his conclusions:

" From a physico-chemical point of view, there is not a great difference between pearlite and sorbite. But sorbite may be obtained side by side with pearlite by hastening the cooling without quenching, or by quenching a steel just at the end of the critical interval, or, again, by reheating a quenched steel to about the same critical interval. For all these reasons sorbite may be considered as pearlite which has not been able to separate into ferrite and cementite by reason of lack of time, or from some other cause, and it seems to be true that it ought to contain a little more ' hardening ' carbon than free pearlite.

" It has been said that sorbite is an unimportant constituent, and several authors have not distinguished it from pearlite. I think this is wrong, and for this reason, that in the first edition of this work I did not give with sufficient clearness ideas which were perhaps slightly confused. But if we remember that sorbite, although it can only remain present in annealed steels up to a certain point, is essentially characteristic of ' negative ' quenchings, and that this procedure considerably improves the mechanical properties of the steel, it would undoubtedly appear as legitimate and as necessary to distinguish sorbite from pearlite as it is to distinguish steels cooled naturally in air from steels which have been submitted to ' negative ' quenching, such as oil hardening, double quenching, or tempering above blue heat. In my opinion it is very probable that the present methods in the manufacture of rails, etc., will eventually appear primitive, and I hope that the greater quantity of pearlite in our steel will be replaced in future practice by sorbite.

" From the point of view of micrography, sorbite is characterized by the absence of striæ, and by the property of coloring rapidly by polish-attack, or by tincture of iodine, even when the latter is diluted with its own volume of alcohol."

Now this particular condition, or variable condition of the carbides in iron and steel, had never previously had a term given it,

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*See "Metallography." By F. Osmond. London: C. Griffin & Sons, Ltd., 1903

although it has nevertheless marked properties and distinct micro-
scopic features, and can be readily detected in steel containing it.
So distinctive are the properties which it confers on steel that for
years it has been the practice of steel manufacturers, at consid-
erable expense, to oil-quench heated steel in order to obtain in-
creased toughness and strength, and for wire manufacturers to
patent their wire rods to arrive at a similar result. It is the sorbite
produced which confers greater tenacity and toughness to the
steels.

Again, the marked difference in the behavior to etching fluids
on annealed and negatively quenched and tempered steels is an-
other justification for giving a distinctive term.

On the table before you are small pieces of steel which have
been heated at one end only to a bright red heat, and were then
removed from the fire and allowed to cool in the air; the portion
heated above the critical point Ac1 has been etched with picric acid.
Note the remarkable difference. The heated ends are dark brown,
the cold ends are nearly white, and the border between the white
and dark portions is most distinct (Photo No. 1). Although high
carbon steels, the dark parts can be readily cut, but they are much
tougher and stronger than the white parts. The darks parts con-
tain the substance called sorbite in large quantities; the white por-
tions are almost pure pearlite, with only traces of sorbite.

High power magnifications also show an equally marked dif-
ference. Although there are distinct traces of incipiently separated
carbide, between these microscopic particles is a dark amorphous
ground mass quite different from the ground mass of the pearlite
in the white portions. This dark ground mass is no doubt unsegre-
gated pearlite, or what may be described as carbide of iron and iron
in a nascent state of separation.

Finally, we welcome the compliment given to one of our great-
est scientists by Mr. Osmond, for associating the name of Dr.
Sorby of Sheffield, the pioneer of micro-metallographers, with
one, if not the most important, constituent of steel, one which will
play a very important part in the future development of our great
industry.

### Description of Experiments in Making Sorbitic Rails

On most carefully studying the effect of oil-quenching on
steel, we found, as was naturally expected, that the proportion of
sorbite is great or small according to the size of the mass

quenched. The central portions of large masses after treating contain less sorbite than the exterior portions.

If, on the other hand, the section of the steel quenched is very light, one may readily have in addition to sorbite some of the more brittle constituents of steel.

Similarly, when steel is air hardened, it may contain practically no sorbite if the mass is great, and much of it if the section is slight. For instance, a wire rod ¼ inch in diameter and a fine wire made from the same steel containing 0.70 per cent carbon, when cooled in air from the same initial temperature, say 850° C., become, the first sorbitic and tough, while the second will be in an intensely hard or brittle condition.

Steel wire rods, after passing through the patenting process, which consists in heating to a temperature at which the steel " scales " and then cooling more or less rapidly through the critical points, contain large quantities of sorbite, readily detected by the microscope after etching, or by the comparatively dark color the whole surface assumes when etched side by side with the rod before patenting.

The property of enabling the patented rod to be drawn to a much greater fineness than is possible in the unpatented material is undoubtedly the effect of the sorbite present.

We naturally concluded that if sorbite is responsible for the excellent qualities of oil-quenched steel and negatively quenched steel wire rods, there is no reason why it should not be produced in steel rails, tires, etc., without great expense.

With this object in view we first experimented on 5-feet lengths instead of complete rails, but instead of allowing them to cool, we plunged them at once into cold or warm water, and afterwards reheated till they were a barely visible red — that is, to a temperature of about 500° C.— after which treatment they were most thoroughly tested. The results are as follows:

### Series " A," " B," " C," " D," and " E "

#### Manufacture

Series " A."— Manufactured from hæmatite on the basic
open-hearth.
" " B."— Basic Bessemer steel.
" " D."—          "          "
" " E."—          "          "

## Section

Series " A."— 60 lbs. per yard flat bottom rail.
    "   " B."— 60     "     "     "
    "   " C."— 85.5    "     bull head rail.
    "   " D."— 60     "     flat bottom rail.
    "   " E."— 60     "    . "     "

## Analysis

|            | "A"  | "B"  | "C"  | "D"  | "E"  |
|------------|------|------|------|------|------|
| Carbon . . . . . . . | 0.29 | 0.31 | 0.40 | 0.45 | 0.48 |
| Manganese . . . . . | 0.72 | 0.72 | 0.73 | 0.57 | 0.82 |
| Silicon . . . . . . . | 0.02 | 0.03 | 0.03 | 0.04 | 0.06 |

*Treatment of the Rails of each Series after Cutting at the Hot Saw.*

A1.— Normal; allowed to cool down in air.

A2.— Quenched in hot water; reheated to 550° C. (16 minutes), and allowed to cool down in air.

A3.— Quenched in hot water; reheated to 500° C. (12 minutes), and allowed to cool down in air.

B1.— Normal; allowed to cool down in air.

B2.— Quenched in boiling water; reheated to 650° C. (30 minutes), and allowed to cool down in air.

C1.— Normal; allowed to cool down in air.

C2.— Quenched in hot water; reheated to 550° C. (40 minutes), and allowed to cool down in air.

D1.— Normal; allowed to cool down in air.

D2.— Quenched in cold water; reheated to 550° C. (50 minutes), and allowed to cool down in air.

D3.— Quenched in warm water; reheated to 500° C. (30 minutes), and allowed to cool down in air.

D4.— Quenched in hot water; reheated to 450° C. (30 minutes), and allowed to cool down in air.

E1.— Normal; allowed to cool down in air.

E2.— Quenched in hot water; reheated to 550° C. (40 minutes), and allowed to cool down in air.

E.3— Quenched in hot water; reheated to 500° C. (25 minutes), and allowed to cool down in air.

E4.— Quenched in boiling water; reheated to 450° C. (40 minutes), and allowed to cool down in air.

*Mechanical Tests*

| Series Number | Treatment | Impact Test* | | Tensile Test | | | | Hardness Number. Brinell's Method |
|---|---|---|---|---|---|---|---|---|
| | | Deflection after 1st blow. Inches | Deflection after 2nd blow. Inches | Yield Point Tons per Sq. In. | Ultimate Stress. Tons per Sq. In. | Elongation Per Cent in 4 Inches | Contraction of Area Per Cent | |
| A1 | Normal . . . . | $3\frac{11}{16}$ | $7\frac{3}{16}$ | 21.30 | 35.90 | 21.00 | 45.80 | 107 |
| A2 | Reheated, 550° C . | $3\frac{1}{2}$ | $6\frac{3}{8}$ | 23.25 | 39.20 | 23.00 | 56.20 | 126 |
| A3 | " 500° C . | $2\frac{7}{8}$ | $5\frac{1}{2}$ | 24.50 | 46.00 | 16.00 | 48.20 | 136 |
| B1 | Normal · . . . | 4 | $7\frac{5}{8}$ | 25.20 | 35.60 | 20.00 | 36.00 | 116 |
| B2 | Reheated, 650° C . | $3\frac{9}{16}$ | $6\frac{11}{16}$ | 29.20 | 39.20 | 16.00 | 40.10 | 125 |
| C1 | Normal . . . . | $2\frac{1}{8}$ | $3\frac{5}{8}$ | 26.60 | 41.10 | 18.00 | 35.50 | 147 |
| C2 | Reheated, 550° C . | $1\frac{11}{16}$ | $3\frac{1}{16}$ | 27.10 | 46.70 | 16.00 | 36.00 | 164 |
| D1 | Normal . . . . | $3\frac{3}{4}$ | $7\frac{3}{16}$ | 22.60 | 43.50 | 16.00 | 32.80 | 144 |
| D2 | Reheated, 550° C . | $2\frac{13}{16}$ | $5\frac{3}{8}$ | 20.65 | 52.80 | 13.00 | 30.40 | 175 |
| D3 | " 500° C | $2\frac{11}{16}$ | $5\frac{1}{8}$ | 22.90 | 52.00 | 13.00 | 24.70 | 165 |
| D4 | " 450° C . | $2\frac{7}{16}$ | $4\frac{11}{16}$ | 22.20 | 54.90 | 12.00 | 28.10 | 211 |
| E1 | Normal . . . . | $3\frac{7}{16}$ | $6\frac{5}{16}$ | 23.10 | 45.20 | 13.00 | 22.10 | 169 |
| E2 | Reheated, 550° C . | $2\frac{11}{16}$ | $5\frac{1}{16}$ | 31.90 | 51.10 | 15.00 | 40.20 | 177 |
| E3 | " 500° C . | $2\frac{9}{16}$ | $4\frac{13}{16}$ | 34.90 | 58.90 | 11.00 | 23.90 | 197 |
| E4 | " 450° C . | $2\frac{3}{8}$ | $4\frac{3}{8}$ | 32.00 | 64.50 | 7.00 | 10.75 | 222 |

\* Weight of ball = 2240 lbs. Distance of drop = 10 feet. Supports apart = 3.5 feet. Length tested = 5 feet. Diameter of ball = 10 millimetres. Load applied = 5000 kilogrammes.

In testing by Brinell's method a number of impressions were made on each rail, and the results obtained were averaged, giving the hardness numbers stated in the table.

These results were so satisfactory that we proceeded with further trials, with the object of avoiding the reheating.

As in the previous experiments, we used 5-feet lengths of hot rails, but this time we plunged them into cold water till they were nearly black; they were then removed and allowed to cool in air.

During cooling, the heat still in the interior of the rails in passing outwards tempered the chilled portion, and left the external parts in the sorbitic condition.

We made many experiments, varying the conditions for each. In some cases we simply sprayed the heads; in others, we plunged the whole 5-feet lengths of rail into water till the temperature was reduced to just visible redness, and in each case they were then allowed to temper themselves by cooling in the air. Experiments were also made to determine the effect of placing the heads to various distances under water.

We had often previously seen attempts made to improve the properties of rails by spraying them, but in no case was the water used in sufficient quantity to produce a material quantity of sorbite, and it invariably produced only carbide and ferrite areas, which were left occupying the same relative volume as in the same rails cooled naturally. There was, however, a distinct improvement in the strength, owing to a small quantity of sorbite present.

Our work has shown that a maximum quantity of sorbite can only be obtained by rapid cooling to below the critical points followed by tempering by external or the internal heat of the partially chilled steel.

Photographs are exhibited, which indicate most clearly the difference between sorbitic and ordinary steel.

All the sections were polished and strongly etched in 20 per cent nitric acid in water for the same length of time, so that the results are strictly comparative.

*" F " and " G " Series.—North-Eastern 90-lb. B. H. Rails*

### Analyses

|  | "F" | "G" |
|---|---|---|
| Carbon . . . . . . . . | 0.49 | 0.45 |
| Manganese . . . . . . . | 0.69 | 0.79 |
| Silicon. . . . . . . . . | 0.02 | 0.02 |

### Treatment

F1.— Normal; allowed to cool down in air.

F2.— The upper half of rail head quenched in cold water to blackness, then allowed to cool down in air.

F3.— The whole rail head quenched in cold water to dull red, then allowed to cool down in air.

G1.— Normal; allowed to cool down in air.

G2.— The upper half of rail head quenched in cold water to blackness, then allowed to cool down in air.

G3.— The whole rail head quenched in water until very dull red, then allowed to cool down in air.

## Impact Test

Weight of ball. . . . . . . 2240 lbs.
Distance of drop . . . . . . 15 feet
Supports apart. . . . . . . 3 feet
Length of rail tested. . . . . 5 feet

| Series Number | Deflection after 1st blow. Inches | Deflection after 2nd blow. Inches |
|---|---|---|
| F 1 | $1\frac{13}{16}$ | $3\frac{3}{16}$ |
| F 2 | $1\frac{13}{16}$ | $3\frac{3}{16}$ |
| F 3 | $1\frac{7}{8}$ | $3\frac{1}{4}$ |
| G 1 | 2 | $3\frac{5}{8}$ |
| G 2 | $1\frac{15}{16}$ | $3\frac{3}{8}$ |
| G 3 | $1\frac{7}{8}$ | $3\frac{5}{16}$ |

## Tensile Test

The test piece of each treated rail was taken from the upper part of the rail head.

| Series No. | Yield Point. Tons per Sq. In. | Ultimate Stress. Tons per Sq. In. | Elongation Per Cent in 4 Inches | Contraction of Area Per Cent | Hardness Number. Brinell's Method |
|---|---|---|---|---|---|
| F1 | 23.50 | 37.20 | 19.00 | 28.80 | 158 |
| F2 | 31.10 | 44.40 | 16.00 | 35.00 | 162 |
| F3 | 33.30 | 45.20 | 10.00 | 30.50 | 187 |
| G1 | 22.50 | 36.50 | 22.00 | 28.00 | 145 |
| G2 | 30.70 | 47.50 | 16.00 | 35.80 | 193 |
| G3 | 32.00 | 49.00 | 13.50 | 30.00 | 204 |

## Series " H."— 60-lb. Flange Rails

" N " is the normal rail.

" S " was sprayed with water imperfectly. The darkened parts, representing the sorbitic regions, indicate where the most water was applied.

" H.S."— Only the head was plunged into water till it was cooled to a barely visible redness.

" W.W." was plunged into water completely to barely visible redness.

In each case after the water treatment the rails were allowed to cool out on the rail bank to temper themselves.

These experiments were made on Finland State rails for the engineer of the Finland State Railways.

The dark appearance of the sorbitic portions are in marked contrast to the greyish white color of the normal steel.

### Analysis

|  | Per Cent |
| --- | --- |
| Carbon. | 0.38 |
| Manganese | 0.83 |
| Silicon. | 0.025 |

### Mechanical Tests

The test pieces were taken from the centre of the rail heads, and do not, therefore, represent the properties of the upper layers of the rails where there was most sorbite.

| Series No. | Impact Test* | Tensile Test | | | |
| --- | --- | --- | --- | --- | --- |
|  | Deflection after 1st Blow. Inches | Yield Point. Tons per Sq. In. | Ultimate Stress Tons per Sq. In. | Elongation Per Cent in 8 inches | Contraction of Area Per Cent |
| N. . . . . | $2\frac{9}{16}$ | Not taken | 43.60 | 17.00 | 32.60 |
| S. . . . . | $2\frac{3}{8}$ | " | 44.20 | 16.00 | 31.50 |
| H. W. . . . | $2\frac{3}{16}$ | " | 46.40 | 16.00 | 31.30 |
| W. W. . . . | $1\frac{9}{16}$ | " | 50.70 | 11.50 | 28.00 |

* Weight of ball = 2240 lbs.   Distance of drop = 10 feet.   Supports apart = 3.5 feet.   Length tested = 5 feet.

The micro-structure of the sorbitic and pearlitic portions show a most marked difference. The pearlitic or normal portion is that

of a heterogeneous mixture of ferrite and sorbitic pearlite, whereas the sorbitic portion is almost perfectly homogeneous.

When the metal was suddenly cooled the carbon or carbides were diffused in solid solution, did not segregate into the normal carbide areas, and were retained in solid solution; but on tempering, owing to the rigidity of the mass at comparatively low temperatures, although the carbides must necessarily fall out of solid solution more or less completely, they remain in what we have previously compared to a nascent state of separation.

The result is that the carbides and iron are left in a most intimate state of admixture, and the structure of the steel is very homogeneous.

### Relative Wear

In order to ascertain the relative wearing property of pearlite and sorbite steels, we would have been glad if we could have presented actual results of wear on a permanent railway track over a period of several years. As this was, however, impossible, we endeavored to get some indications by other means. The method we finally adopted was that of grinding on a freestone grindstone, using equal surface pressure and distance travelled. In applying this test, we cut out pieces from the heads of both the rails ½ inch in thickness and 1 inch square. These were carefully weighed, and were pressed on the surface of the revolving grindstone by a weight of 72 lbs. until they had travelled a distance of 20,000 feet. They were then removed and weighed. The tests were repeatedly made on the same pieces. The results are as follows:

|  | Average |
|---|---|
| Pearlite rails . . . . . . . . . . . . . . . . . . | 0.100 |
| Sorbite . . . . . . . . . . . . . . . . . . . . | 0.33 |

The results are decidedly in favor of the sorbite rails. Whether or not they will be borne out in practice remains to be seen. It seems most reasonable to believe that such homogeneous material as the sorbite steel, much tougher than the same steel in the pearlite condition, will certainly last much longer on the permanent way.

### Summary

The chief point of interest in our work is the simple method employed for producing sorbite in steel. The usual custom has

been to reheat and oil-harden or to quench completely in water and reheat to dull redness. In our method we avoid reheating, and quench the heads of the rails, as soon as they are sawn to length, to a point under $Ar_1$, and allow the residual heat in the rails to do the tempering. The results of the later experiments show clearly enough that by partially quenching the heads and allowing the rails to temper themselves, although the elongation is decreased, the contraction of area remains practically the same.

The normal rail in " F " series of 37 tons tenacity when made sorbitic is increased in strength to 45 tons without diminution of the contraction of area.

In " G " series the normal rail with 36½ tons tenacity is increased to 49 tons with a slight increase in the contraction of area.

In the last series (Series " H ") the tenacity is increased from 43 to 50 tons with a slight diminution in the contraction of area.

Pieces of the rail cut from the area of maximum sorbite on being tested by repeated reversals of strain showed greater toughness and endurance than the normal material.

The wear is very greatly in favor of the sorbitic material, as would naturally be expected, and we are sanguine enough to believe that by specially treating the rails in the simple manner described their life will be increased from 25 to 50 per cent.

The splendid results obtained by Mr. Brinell on quenching steel from about 850° C. and reheating to 550° C., and the results quoted by Mr. H. Le Chatelier, and the evidence given by Mr. Osmond, together with what has been advanced in this paper, all point in one direction, and should lead every iron and steel metallurgist to aim at replacing pearlite by sorbite in all structural steels which have to be subjected to friction, percussion, or vibration when in use.

Finally, we may point out that although it is quite easy to treat hot rails in short pieces, we have not yet completely succeeded in treating 30-feet lengths satisfactorily. Our work is, however, far from complete, but we hope that before long we shall be able to report a complete success.

Our sincerest thanks are accorded to Mr. David Evans, Mr. E. H. Cook, Mr. R. C. V. Whitfield, and our assistants.

## BEARDSHAW'S SORBITIC STEEL *

WE illustrate below a specimen of the " sorbitic steel," made by Messrs. J. Beardshaw and Son, Limited, of the Baltic Steel Works, Sheffield, which possesses most remarkable and valuable physical properties. The specimen shown was cut from a 5½-inch bar and was originally 1½ inches square. It has, as our illustration shows, been bent double, and though it has been flattened a little in the process, there is not the sign of a crack any-



where about it, even although the edges of the specimen were left dead sharp, in place of being rounded off, as is commonly done before making a bending test of steel. The makers inform us that in its original state the bar from which this specimen was cut had a breaking strength of 35 tons, an elastic limit of 18 tons, and an extension of 29 per cent in 2 inches. It was then subjected to the firm's special heat treatment, which has conferred on it the remarkable toughness indicated in our illustration; and on making new tensile tests, it was found that its strength had been raised
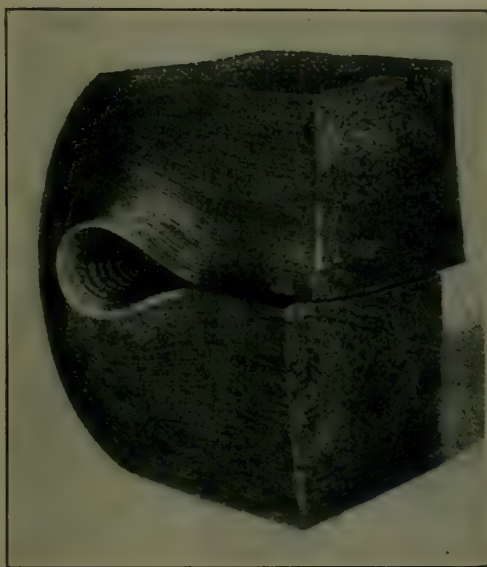
* *Engineering,* October 16, 1903.

to 48 tons, and the elastic limit to 38 tons, while the extension on 2 inches was 23 per cent and the reduction of area on fracture 47½ per cent. A steel of this kind should prove most valuable for very many purposes where lightness and strength are required in combination. It is not in any way a hard steel, and can be cut and filed easily. Possibly even these steels may at a later date find application to structural purposes. Its makers even now can supply it in fairly large sizes, and they claim that they can readily attain even greater strength and toughness, if such is required by their customers.

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## POWER FROM BLAST FURNACES*

PROBABLY the greatest impetus has been given to the large gas engine by blast-furnace gas utilization. 'It was only in 1896 that the writer made the first public and independent test of the first gas engine ever worked with blast-furnace gas, says William H. Booth in *Cassier's Magazine*. Since that time the use of such gas in gas engines has become comparatively common. More has been done upon the Continent of Europe than in Great Britain, but much more would have been done had not the Continental engineers get hold of the curious and erroneous idea that blast-furnace gas could be used in the gas engine with all its load of grit and dust without cleansing. Though progress has been slower in Great Britain, no British engineer has proposed such a folly as this, and the British cleansing method of Thwaite, the originator of the whole system, has now received universal recognition as an essential part of the utilization of this gas.

If the gas furnace were used to its full capacity it would provide power in immense quantities, and this could be electrically transmitted by high-tension lines to centres of large industry or population. Transmission can be effected only electrically; hence the demand which is growing up for large gas engines that will run steadily enough to drive alternating-current machines.

While the blast furnace has done, and will do, so much for the large gas engine, it may be pointed out that gas power plants have probably failed in the past because of the difficulty with pre-

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* *Iron and Steel Trades Journal*, October 17, 1903.

mature explosions due to gas too rich in hydrogen. Blast-furnace
gas has been called miserable stuff, because it will hardly burn
at atmospheric pressure in the cold vicinity of steam boiler plates,
and Mr. Tom Westgarth states that when burned under boilers it
will not produce more than one-fourth the power that it will give
when used in gas engines.   More favorable estimates give the
ratio at even a sixth.   In any case, the difference is so great that
the gas engine must inevitably be the future user of blast-furnace
gas.

## UNIFORMITY IN "MALLEABLE" HEATS*

A RECENT patent issued to Dr. R. Moldenke on a process of
    producing uniformity in molten material, is of especial
interest to producers of malleable castings, as it aims at over-
coming one of the bugbears of the ordinary malleable process in
the air furnace or on the open hearth.

Those who are familiar with this branch of the foundry trade
will know that when the bath of metal is skimmed, and " up " in
heat, so as to be ready to pour, the tapping of the melt at its lowest
point brings out the metal from the lower part of the bath first.
This metal is usually much colder than at the top of the bath, where
it has been under the full stress of the flame, and yet it is generally
from this top iron that a test plug is cast, on which the metal of
the bath is adjudged ready for pouring or not.   The consequence
of this is that usually the first iron is too cold for thin castings, as
these will not run properly.   It is also too cold for the heavy work,
as this will not chill properly.   It will only do for the medium
classes of castings, to pour which, and not the others, is the earnest
endeavor of the foreman in charge, with more or less chances of
success.   Castings which are mis-run are weeded out and charged
to profit and loss.   Castings which are " low," that is, badly
mottled or even grey, are not detected so easily, and the result of
the anneal is bad iron, only detected by the customer when some-
thing breaks.   In describing the conditions which led to the per-
fecting of his process the inventor says: We will suppose the
stream to be running from the furnace at the usual rate of about
three-quarters of an hour for a ten-ton heat.   The top iron was

*\* Iron and Steel Trades Journal, October 24, 1903.*

just right when the metal was tapped. This top iron is the last to come out, and doing so over half an hour after it was of proper composition and temperature usually means " high " or partly burnt iron. This is the case, no matter whether the fuel was cut off or not, as the highly overheated iron is certain to absorb gases, and deteriorate in quality. The consequence is metal which may show only small pin holes, or may be so badly burnt that it will not anneal at all. Here, then is a loss also, and it is perfectly well understood in the malleable foundry that the end of a heat may not go into important light castings, where its use would seem most desirable. Often the last of a heat goes directly into annealing pots, to avoid any chance for trouble. With about one-quarter of a heat liable to cause difficulties, there is little wonder that attention has been given to the matter by the best minds, and the only solution of the problem would seem to get the hot metal off the top first, in fact, reverse the usual method of tapping, as it were. The heavy slag cover protects the metal in the steel process, so also to some extent the slag formed in the air furnace where grey and chilled castings are made, though this is by no means perfect. In " malleabie," however, the very thing that seems most essential, the getting of the top iron first, has heretofore been impossible.

The most rational solution is therefore the tilting furnace. Here we have the ideal condition of pouring off the hot iron from the top just as we wish. The last iron comes off from the bottom, where it was least affected by the gases, or subject to the reactions going on in the bath, the uniformity of a bath of melted metal not always being as perfect as is generally imagined.

The tilting furnace has several disadvantages, the two most important being the first great cost and the high bill for repairs. Malleable works do not invest in large units when it comes to melting iron, the sensitiveness of the process, when taken in connection with the length of time it takes to tap a heat, precluding this. So the tilting furnace will remain away some time yet. In the patent referred to the arrangement is to replace the usual single spout placed at the lowest point of the bath, by two or more at different levels, the idea being to tap the upper one first. When the top of the metal is thus removed, the second spout is tapped. Then the next, and so on. In actual practice a 15-ton furnace is provided with three such spouts, and experience shows that when

the upper iron is off, the heat may be left under fire for some time before it becomes necessary to tap again, to prevent burning. The important point is gained in that the iron is never overheated to endanger its quality as malleable where this method is used, and the cost of the furnace no more than the ordinary.

In actual practice with this arrangement, the heat is tapped three times into six-ton ladles each time, this metal, after being brought to the proper distributing point, going into the regular shanks and hand ladles. Usually the last 500 pounds are left in the first ladle when it goes back to the furnace; the second pour, and, finally, the third is used to the last drop in all classes of castings indiscriminately, the first ladle going into everthing but the very smallest work; this on account of the chilling effect of crane ladle and hand ladle combined, before the moulds are reached. The process is, however, equally good for the regular method of catching the metal off the spout in hand ladles, or for chill roll work and gun metal from the air furnace.

The difficulties met with in turning out good metal, and then getting it into the proper moulds suited to its composition and temperature, are seldom realized by those who think of and do go into the malleable casting industry.

## THE MICROSCOPE IN ENGINEERING: ITS WIDENING USE IN STUDYING THE STRUCTURE OF METALS*

### By J. L. HALL

ENGINEERS base their selection of material on their knowledge of its peculiarities. From many years of experience in both laboratory and mill a vast amount of data, relating to both physical and chemical qualities, have been acquired. By careful scientific testing the values given to the constants which enter into engineering formulæ have been determined, and practice has demonstrated their truth; yet to-day how far from absolute confidence is the feeling of firm security regarding calculations! The use of the empirical factor of safety, historic sometimes and arbitrary always, the figure 6, is positive proof of a feeling of insecurity in materials, and we endeavor to shield our ignorance of the

strength of the materials entering into a design by holding up before us as an apology our lack of knowledge in originating the design itself.

Quality in the grade of metal used in structures and mechanical appliances has in the past been considered synonymous with chemical composition; yet to-day we are quite sure this is not absolutely true. Of late another factor has gradually crept in which has a far-reaching and most important bearing on the question of quality. I refer to heat treatment. The old saying, " True as steel," no longer typifies reliability. To aid in ascertaining the reasons for unexplained failures engineers have turned to the microscope in the hope that at last many enigmas would be solved.

It may be well to state here that the microscope is not expected to answer every question which has arisen regarding materials. Neither can we hope always to apply the knowledge we have obtained by its use to a practical end. Its reliability in determining the physical properties of steel, for instance, has often been questioned. Most sweeping were the claims for results of chemical investigations when they were first applied in manufacturing, and much was expected from them which, it has since been proved, was beyond their inherent power to accomplish. All sciences have their limitations. So it is with metallography, — the name generally given to the science which applies the microscope to ascertain the structure of metals and alloys.

Metallography, however, is not a purely descriptive science, or its application to the various lines of industrial work would be extremely limited. It goes much farther and deals with the relation between structure and those properties upon which the value of metals depends.

It is difficult to fix the date of the production of the first microscope as distinguishable from a mere magnifying lens; but it was propably about the year 1600, and evidence points to Galileo as the man who developed it. Its history, while interesting in the abstract, can only be referred to here. To the first instrument improved objective eye-pieces and accessory apparatus were added, new designs permitting of finer adjustments were adopted, until to-day the microscope is an instrument of the greatest precision and usefulness. The needs of metallography have, in late years, made new demands, requiring special modifications in the auxil-

iary apparatus; but, in general, the microscope of the metallographist is also the microscope of the botanist and the biologist.

To a student, Dr. Henry Clifton Sorby, of Sheffield, England, is due the honour of the pioneer work in metallography. All other workers in the field, both scientists and engineers, who have since helped so materially to develop this branch of science to its present condition of exactitude have followed Dr. Sorby's footsteps. Not directly interested in metallography, but a student of geology and mineralogy, he applied the microscope to the study of rocks, and it was for him a natural and sequential step to apply it to the investigation of metal structures.

Yet, when he presented a paper in 1864 before the British Association, treating of this method of examination, he attracted little attention, and the paper was merely filed for future consideration, which it did not receive until twenty years later, when the Iron and Steel Institute invited Dr. Sorby to become a member of a committee selected to investigate the practicability of applying the microscope in the examination of the internal structure of steel. The result of this action was a second paper by Dr. Sorby, which should be considered the first milestone on the road between the adoption of the microscope for purely scientific research and its application to practical uses by the engineer.

Probably everything has its strong points as well as its weak ones. Should the advantages of a particular device outweigh' its disadvantages, we adopt it; *vice versa,* and we discard it. So in considering the use of the microscope in engineering, we must balance the arguments for and against it. Why should the engineer, and by this term is meant not only the individual in his capacity as a scientific analyst, but the industrial engineer as well, consider any new method of testing his materials? Has he not already a well-developed system of investigation covering tensile, torsion, compression, and drop tests? Does not chemical analysis tell all about the composition of metals? Does he not know that so many hundredths of one per cent of phosphorus make steel brittle? So much sulphur, red short? In any case, if it be suspected that something is wrong, cannot a piece of the metal be cut directly from the thing itself, turned into a half-inch test piece and put through certain destructive processes to prove, perhaps, the truth of the suspicion?

Can he not break a 1-inch bar into pieces and note the frac-

ture, a coarse appearance implying weakness, while a fine grain signifies strength? Can he not treat his metal with some suitable reagent and find the cause of the trouble? What if the material is defective! He can discover the fault by one of these two methods and a knowledge of the structure of metals is of little importance. Such are some of the arguments against the use of the microscope in testing. Do these arguments stand upon a sound foundation of fact?

Granting that the testing machine will reveal defective material, we know from its use merely that certain pieces are defec-
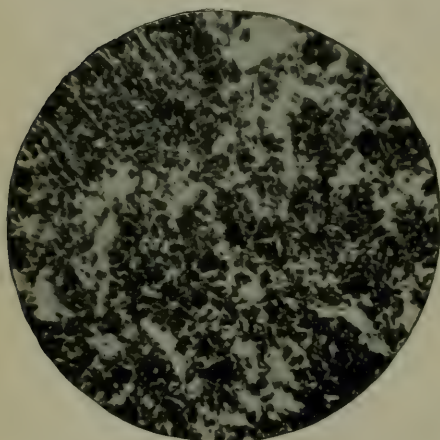


Fig 1.    Photo-Micrograph of Steel after       Fig. 2.    Steel after Heating to 750° C. and
Heating to 750° C. and Cooling in the                    Cooling in the Furnace.
Air.    Magnified 100 Diameters.

tive. But what will be the next step in the investigation of the cause? Why should we not expect the next casting or forging to be just as defective? We have not diagnosed the case, far less suggested the remedy. But we can certainly ascertain a remedy, we are told, by chemical investigation, and, in truth, chemical composition and physical properties are closely affiliated; but a glance at the annexed illustrations will make it sufficiently clear that there is a factor entering into the strength of the metal not chargeable to the component elements. Fig. 1 shows the structure of a piece of steel magnified 100 times. This piece contains 0.33 per cent of carbon, 0.60 per cent of manganese, 0.065 per cent of sulphur, 0.56 per cent of phosphorus, and has been heated to 750° C.

and cooled in the air. Fig. 2 shows a piece of the same steel, heated to the same temperature, but cooled in the furnace. Figs. 3 and 4 show the same steel after heating to 1,000° C., and respectively, air and furnace cooling.

The Fig. 1 specimen had a tensile strength of 89,000 pounds per square inch, with an elongation of 26 per cent in 2 inches; Fig. 2 showed 78,680 pounds tensile strength, with 29 per cent elongation; Fig. 3, 102,850 pounds and 23.5 per cent elongation; and Fig. 4 showed 81,650 pounds, with 26 per cent elongation. The maximum variation in tensile strength, therefore, is 30.5 per
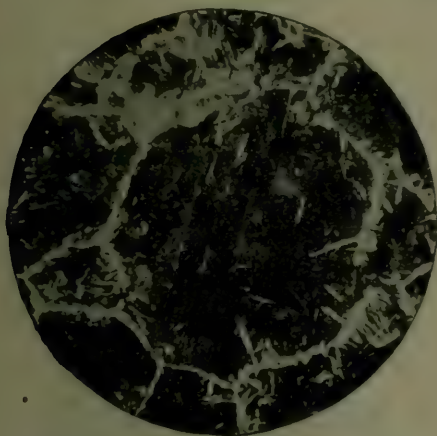


Fig. 3. Steel after Heating to 1,000° C. and Cooling in the Air.  Fig. 4. Steel after Heating to 1,000° C. and Cooling in the Furnace.
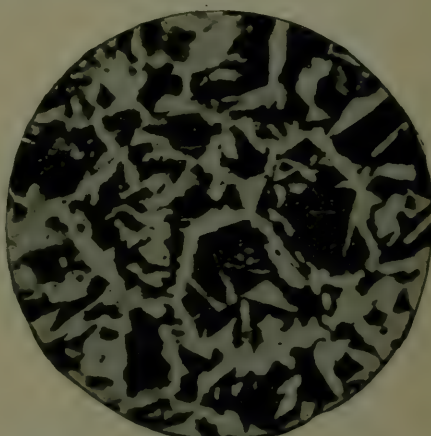
cent, and the variation in elongation is 26 per cent, yet the chemical composition of the four specimens is identical. Why is this?

It is evident that heat treatment has produced an effect upon the physical properties, and the microscope has revealed the fact that a corresponding change has taken place in the structure of the metal. Take a steel rail, for example. When the fractured surface appears coarse to the unaided eye, it will follow that the microstructure is coarse; but when the fracture appears fine, the microstructure may or may not be necessarily fine, though a fine fracture always accompanies a fine microstructure.

Again, examine the two babbitt metals illustrated in Figs. 5 and 6. Both are of the same chemical composition, yet the difference in structure is apparent, and the merest novice in metallo-

graphical study would unhesitatingly pick out the first with its homogeneous structure as the better metal of the two. Briefly, it may be stated that these examples, which are indicative of the results of study in this field, show that the treatment upon which the microstructure depends has an important bearing upon the physical and chemical properties of the metal. It is just as important to know whether a metal is defective because of the unintelligent treatment as from ignorance in proportioning its chemical composition.

The first practical application of microscopy to the study of metals was made to steel, and the fact that this metal plays such an important part in the industrial world to-day gives prime importance to any method that will better its production. Treatment which may or may not have been thermal has an important bearing upon the microstructure. The ultimate requirement is that a material, when manufactured, shall in every respect satisfy the purpose to which it is applied. The maker may provide a metal suited to the requirements, and it may fail in the end through faulty treatment by the user.

The question then arises:— Who is to blame, and what steps
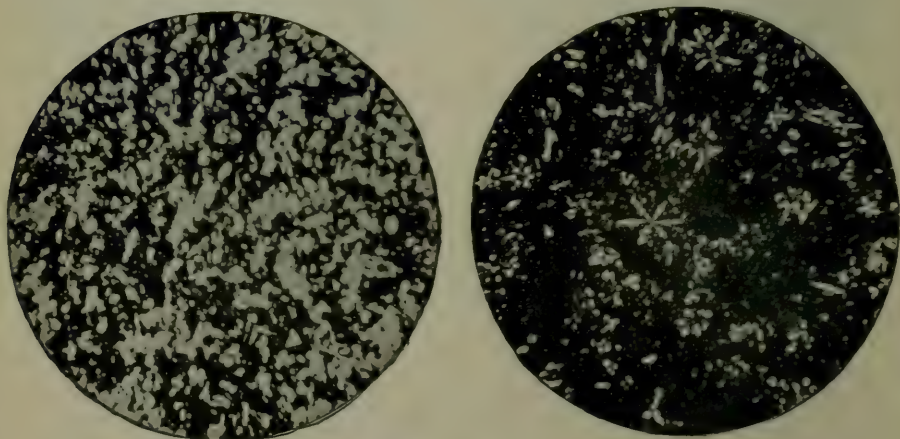


Figs. 5 and 6. Babbitt Metal Sections, Magnified 100 Diameters.

shall be taken to apply a remedy? Chemistry alone cannot answer this question, but the microscope in conjunction with it will aid materially. It will reveal whether an ingot or a billet as received

was of the proper structure after chemistry has determined the composition. The forging or rolling or other process through which the metal subsequently passes will leave its mark upon the microstructure, and another examination will indicate the defects produced during this process, should defects exist. Every sequential treatment produces an effect upon the microstructure at its corresponding period.

The Kennedy-Morrison process of rolling rails is an example of this. Here advantage is taken of the grain-refining action of rolling steel at a comparatively low temperature, accomplished by retaining the rail for a short time upon a cooling bed before passing it through the finishing rolls. The improvement in quality is so great that in order to put the process in operation at the Edgar Thomson Steel Works, in Pittsburgh, the rail mill was shut down for an extended period in 1900 until apparatus was properly installed to produce the desired results. Other American rail mills, benefiting by this experience, have followed the same course.

In many branches of steel work manufacturers equipped their laboratories with metallographical apparatus. Such firms as the John Cockerill Company, at Seraing, in Belgium; the St. Étienne Steel Works, in France; the Bethlehem Steel Company; the Illinois Steel Company; the United States Steel Corporation; the Crucible Steel Company, and many other smaller concerns in the United States have adopted the microscope as an aid in securing the best results. Such a list of names is sufficient argument in favor of the use of this instrument in steel works.

It is to be regretted that, due to some unexplainable cause, the application of the microscope to practical use in iron foundry work has not been so rapid and far-reaching as in steel making. There is no apparent reason to believe that cast iron cannot be studied by the aid of microscopy with as promising results as have been reached in the case of steel. The former is found a trifle nearer the carbon side of the freezing-point curve of carbon and iron alloys than is the latter, but it bears a relation to steel similar to that which copper-zinc alloys rich in zinc bear to copper-zinc alloys rich in copper.

Just as much advance has been made in the study of copper alloys by the aid of the microscope as in the study of steel. When a molten mixture of metals cools down to a solid state, crystals

of a definite chemical composition separate from the solution and may be seen by the aid of the microscope after properly preparing the specimens. Whether the mixtures be of carbon and iron, copper and tin, or other metal ingredients, they differ in degree of interest only, depending upon the problem in hand, and one can be studied with just as beneficial results to engineering as the others.
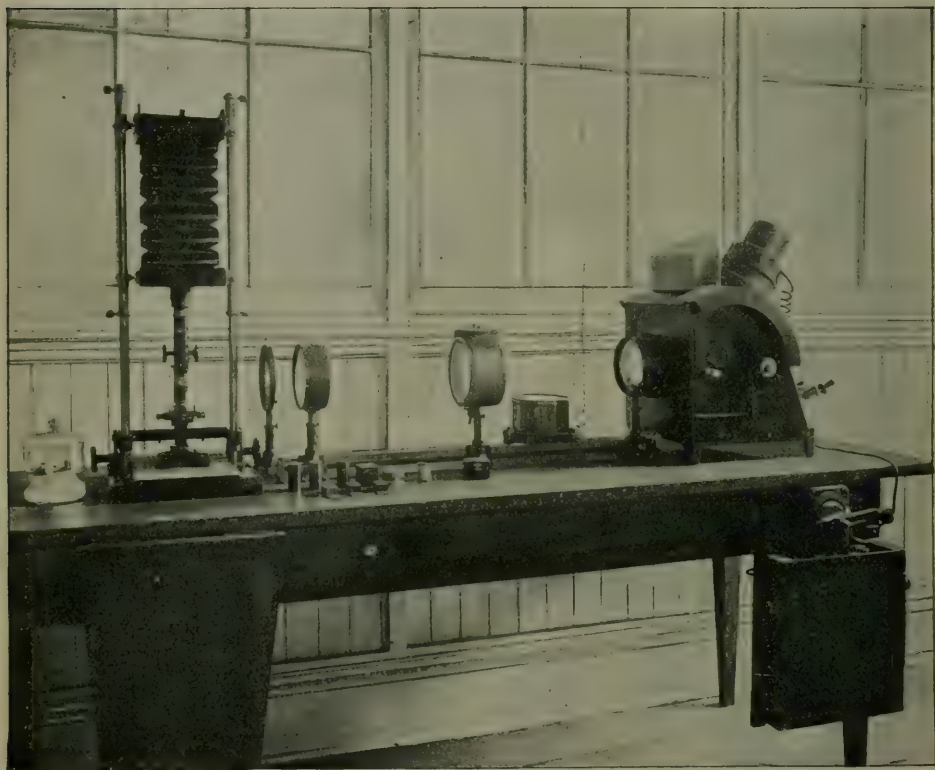


Fig. 7.　Laboratory Outfit for Microscopic Analysis, as used in the Westinghouse Works.

　　　The technology of microscopic metallography has been so ably treated heretofore in the publications of several countries that a mere outline of the usual methods and apparatus employed will be sufficient for the present purpose. Any first-class microscope will answer the purpose. It is necessary only to add to the ordinary equipment a vertical illuminator, as the usual methods of

of illumination where the light is transmitted through the object itself, for obvious reasons, will not answer when opaque objects are to be examined. Artificial light from some source is also required. A gas burner, an incandescent lamp, a Nernst, or an arc lamp with suitable condensing lenses will give satisfactory results. Mount this apparatus on a suitable table, and the investigator is ready for ocular examination of his specimens. Add to this a camera, especially designed to fit the microscope, and he is equipped to record what his previous investigation showed him. In Fig. 7 is shown one arrangement of these appliances. To the right is the lamp, to the left the microscope with camera arranged for vertical manipulation. Between the lamp and microscope are placed two large condensing lenses, a water chamber and Iris diaphragm. This apparatus is capable of such brilliant illumination that the image of the specimen may be thrown directly upon a screen, should several persons desire to make observations at one time.

To prepare the specimen it is necessary first to produce a perfectly plane surface, as free from scratches as possible. The specimen itself may be of any shape and size, limited on one hand by the manipulator's ability to handle it when preparing it, and on the other by the design of the microscope to accommodate it. It may be extremely small or the full section of a 90-pound rail, for example. Care must be exercised, however, in the selection of the sample, so as to have it represent the average structure of the piece and not some abnormal growth of a local nature, and, in some instances, several specimens must be prepared typifying different parts of the same large piece.

For example, a rail section should be polished and etched. Photographs should be taken at many different points, some around the edge, and some through the centre of the web and flange, and a study of each would be required to determine the effect of temperature upon the microstructure as a whole. In securing samples for several pieces for comparison, it is important to select them from the same relative positions in each case. The samples may be round, square, thick, or thin.

The polishing process properly begins with filing, followed by grinding on an emery wheel, then successively on wheels covered with cloth filled with emery powder, polishing powder, and rouge. Often the rouge polishing may be omitted.

After polishing, the specimen is etched by the use of suitable reagents, or is " heat tinted," the latter being a differentiation method, depending for its value upon the formation of colored oxide films, the colors varying with the different chemical constituents in the object examined. It is in etching that the personal factor of the manipulator is most in evidence. Several reagents and methods of their application may be used with equally good results, yet naturally one of these may appeal to the individual more than the others, and that is the one which he will probably use most successfully. In the examination of the etched specimen observation of detail is essential, and the value of the microscopical examination lies in the facility of using such observation to advantage.

Success in photographing the structure comes largely through experience. Conditions differ materially from those existing in ordinary photography; but some skill and patience, coupled with a few trials, will usually suffice to produce good results. Focusing is usually done on a clear glass screen with the aid of a low-power eye-piece, and this method insures very sharp negatives. Exposure may range from one to five seconds, according to the magnification and illumination.

Many details of apparatus and methods enter into the technology of the subject; but while interesting and important, they are not within the scope of this article. It is sufficient here to say that that stage has been reached in the development of the science of metallography at which the time required to complete an examination, including grinding, etching, and photographing, is about half an hour, and is considerably less than that required for the chemical and physical tests. Like the general rules of analytical chemistry, the general methods of metallography may be reduced and simplified as occasion and experience may suggest.

A well-known engineer once said, after listening to a lecture on metallography, that there was a good deal of similarity between bread and steel,— one could combine the right amounts of flour, water, and other ingredients, but a poor cook might spoil the resulting bread. And so it is with any metallic mixture. One may have the component proportions right, and yet, in the making, fail to obtain a product possessing the desired properties. And it is to get around this difficulty that metallography will serve a most useful end.

It can be only after a long and careful study that we can secure full results by the adoption of microscopic methods, and we must keep in mind that the mere aggregation of a large mass of data is far from being all that is required. We cannot expect to apply the knowledge to practical ends immediately; but practical results will be, and have been, obtained through this avenue of scientific research.

## THE MANAGEMENT OF THE BABY BESSEMER WORKS AND THE COST OF WORKING THE PROCESS*

### By LUDW. UNCKENBOLT

SINCE the article which I published in *Stahl und Eisen,* 1903, No. 17, on " The Present State of the Management of Baby Bessemer Works in Belgium," I have been approached by various parties and requested, in case I was in the position to do so, to give still further explanation of the management of the Belgian Baby Bessemer works and the cost of working. In compliance with these repeatedly expressed wishes, I have decided to answer the questions which have been asked me in *Stahl und Eisen,* and I should be much pleased if I might by this means bring about an exchange of opinions.

In my opinion the most suitable content of a converter is a quantity which will produce 1,000 kg. One can easily take greater charges, from 2,000 to 3,000 kg.; but if smaller quantities are used, there is always the danger that the first charge will not be kept hot enough. The walls of the converter absorb, especially at the first charge, quite a considerable amount of heat, which can be provided only with difficulty and expense by hot blast with coke. The coke burns to ashes which, as is well known, is a poor conductor of heat. The floor of the converter is never thoroughly heated by the hot blast, the ashes keep away the heat. The floor receives the right heat only at the first charge.

On the other hand, later, when one or two hot charges have once been obtained by the use of the hot blast, the weight of the charges can easily be decreased. The decreasing of the weight of the charges is especially recommended where light, thin-walled

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* *Stahl und Eisen,* November 1, 1903.

castings are exclusively produced. In spite of the sharpest discipline, in spite of all the dexterity of the founder and the master, the casting of 1,000 kg. of steel into mere little light pieces takes too long a time, the steel grows cold in the converter, does not fill the molds when it is poured out, etc., and there is much waste. Under these difficult circumstances, it is better to diminish, after the first charge of 1,000 kg., to charges of from 800 to 900 kg. The blowing of such small, light charges in a large, hot converter is very successful, but requires a steady, expert blaster. The process is more simple and better if the weight of the charges can be kept up to 1,000 kg. We attempt to make this possible by casting alternately heavy and light pieces. Heavy pieces are more easily made in the Martin furnace; however, in order to regulate the working of the Baby Bessemer some large pieces are manufactured with advantage; such pieces as cog wheels, small screw propellers, and stern posts, etc. One does not make much on such large pieces to be sure, but they make possible the regular working of the Baby Bessemer. We cast then, for example, from 300 to 400 kg. in heavy pieces and the rest from 600 to 700 kg. in small pieces. Then we proceed in this way; first, for example, four or five fork ladles full, containing from 30 to 50 kg., are caught one at a time, directly from the converter. Then 300 to 400 kg. are taken out for large heavy pieces in a crane ladle, then the rest is caught again in small fork ladles. It is not recommended to work with more than four or five fork ladles at the same time, for each ladle gives a skull which becomes cold and so occasions loss of material and heat. All the skulls in the ladles are gathered together, each time after the molds have been filled and are brought while still hot to the converter to be used in the next charge. If the master-smelter is energetic and careful, he can bring about considerable savings in fuel, etc.

Under normal conditions the steel is always so hot that weldings, defective spots, flaws, and cracks made by contraction can be mended. In consequence of the extreme fluidity and the great over heating of the steel, there arise in the working of the Baby Bessemer many more and much smaller contraction cracks, etc. Everything has to be done very quickly and as a consequence the castings are often made too hot. To overcome this evil, it is an unconditional requirement that the pouring of the steel from the converter should be carefully and sharply watched, and the casting

itself should be likewise carefully controlled. If the steel is too hot, then we put into each forkladle, when the steel is poured, a small quantity of clippings, filings, scraps, etc. These pieces dissolve in the steel-bath in the ladle, cool the steel off, and prevent the later formation of contraction cracks, flaws, etc. The fear that by this procedure the steel may become turbulent, I have never been able to observe. Heavily rusted steel ought not to be used for this purpose.

With regard to the manner of working it is unconditionally required to make as many charges as possible, one after another without interruption, from one converter. By this means, quite considerable amount of fuel is saved, for the " bringing to heat " of the cupola furnace, the converter, and the casting ladle, etc., costs much time and much money as is well known. To counterbalance this, castings are made in small establishments only once or twice a week. Well-made casting molds may be used, if carefully protected, and if the weather is not too damp, three or even four or five days. Then the sixth day is employed in clearing out the foundry and unpacking boxes of molds, etc.

It is a good plan to mold in advance and then when a sufficient quantity has been molded it can be smelted and cast. I have often, for the sake of saving coke, made from 16 to 20 charges of 1,000 kg. from a converter in one day. On the next day no castings were made.

With regard to the cost of working, we have to reckon on a loss in a cupola furnace of 7 per cent which goes into the slag. This somewhat high loss is due to the fact that the pig iron must be strongly overheated. If this does not happen, difficulty often arises with the combustion of the pig iron in the converter. If the combustion does not occur evenly, the steel does not become properly heated and later does not become quiet. For this reason the use of coke in the working of a Baby Bessemer plant is naturally much more extensive than otherwise in cast-iron works. On the average, we have to count on 15 per cent coke. Naturally the amount of coke used depends much also on the construction of the furnace, the air pressure applied, the quantity of coke, etc. To make sure of it, it is well to count on the consumption of 20 per cent of coke in the management or working of a cupola furnace.

With regard to the slag, lost in the converter, this depends on

the greater or less skill of the blower. If he works under high pressure of the blast and does not use the regulating ventilators, the loss may reach incredibly high figures. The scrap of the converter increases extraordinarily in such cases. Besides these losses depend much also on the construction of the converter, the arrangement of the blast pipes, etc. In a short converter the loss in scrap is greater than in a longer one. On the other hand, again, with too long, too roomy Bessemer converters the beginning and the end of the operation can only with difficulty be exactly determined. So in this case it is necessary to watch very carefully and diligently in the beginning, to proceed according to a definite plan and with a purpose in mind, for otherwise the manufacture of steel can become very costly. Likewise these losses grow quite considerably if the pig iron comes into the converter not sufficiently hot, and if the converter itself is not thoroughly heated by the hot blast. The composition of the pig iron also plays a very important part here. Pig iron that is too hard and containing too much silicon produces more scrap than that which contains less silicon. White pig iron is more combustible than deep gray, etc. In the beginning this must be duly attended to, later when one has mastered the method of procedure it takes care of itself. The present Baby Bessemer establishments in Belgium work wholly without a chemical laboratory. The management is left wholly in the hands of an engineer; the casting house and the work room are managed by him also.

On an average we have to count on 8 per cent loss (I purposely do not say scrap here) in the baby converter. If we add to this, in the waste, 2½ to 3 per cent for admixtures of ferro-manganese, spiegel iron, ferro-silicon, aluminium, etc., which are used for the deoxidation and recarburization of the steel-bath, it amounts to from 10½ to 11 per cent loss in the converter, which is really the case. We always work, according to the form, size and shape of the casting, with 10, 15, 20, even 50 or 60 per cent of clippings composed of bits left in the molds, pieces that result from filling the molds, filings from the edges of castings which are used to prevent contraction cracks, refuse pieces, waste, etc.

I wish to remark here beforehand that in some well-conducted and well-superintended establishments, clippings need never be sold; but, on the contrary, it is an advantage to buy more when the clippings are cheaper than good pig iron. I have

worked with 20 per cent of clippings, on the average, in the cupola furnace and have thus been able to work up all my clippings and those of the factory workshops besides. Small clippings and filings, etc., are suitable for the cooling, as I have said, in the ladles; larger pieces go to the cupola furnace, or better still direct to the converter.

Coke is necessary for heating the converter, for drying and heating the casting ladles, for drying the molds, etc. In my experience the amount required according to the size or amount of production runs as high as from 1 to 2 marks for 1,000 kg.

Now as an example of what the whole reckoning amounts to: We work with 7 per cent of slag in the cupola furnace, we must then have a charge of 107 kg. to obtain 100 kg. liquid. And we must have a charge of 115.56 kg. to obtain 100 kg. of steel liquid with a further loss of 8 per cent in the converter. To arrange in order: An ordinary quality of Bessemer pig iron stands at 68.50 marks; a better quality of hematite rich in silicon, at 78 marks; smelting coke costs 28 marks; 10 per cent ferro-silicon, 90 marks; 10 to 12 per cent spiegel, 67 marks; scrap, 55 marks; aluminium, 99 per cent, 3 marks per kg.; gas coke, 20 marks, etc. The charge for the cupola furnace is composed as follows:

| | Kg. | Marks |
|---|---|---|
| 400 Bessemer pig iron | $68.50 = 713 =$ | 48.84 |
| 100 Hematite | $78.00 = 178 =$ | 13.88 |
| 150 Scrap | $55.00 = 269 =$ | 14.79 |
| 650 | $1160 =$ | 77.51 |

For 100 kg. liquid steel we reckon on the average,

| Kg. | Per Cent | M. | M. |
|---|---|---|---|
| 14 Ferro-manganese | 80 | 220.00 = | 3.08 |
| 5 Spiegel | 10-12 | 67.00 = | 0.38 |
| 5 Ferro-silicon | 10 | 90.00 = | 0.45 |
| 1 Aluminium | 99 | 3.00 = | 3.00 |
| 25 | | | 6.91 |

$$77.51 + 6.91 = 84.42 \text{ M.}$$

These admixtures it is best to heat somewhat and break into pieces before putting into the converter, immediately after the blasting has begun. The melting down of the admixture before putting it in has no particular advantage but is always quite agree-

able, especially when the charges are not quite hot. The aluminium is put in in ladles. With 1160 kg. in the cupola furnace, as charging material, are used 232 kg. coke at 28 marks = 6.50. According to that, 84.42 + 6.50 = 90.92 marks. For heating, etc., we must reckon 1 to 2 marks which make 92.92 marks. The liquid steel in the Baby converter costs in round numbers 93 marks per 100 kg.

What is paid in molders' wages, trimmers' wages, annealing, ore dressing with sand, etc., may be nearly covered by the amounts paid in the Martin working. I will not fail to give warning that the sand ore dressing plays an important part and that one can save himself much vexation and trouble, if one gives to the preparation of the molding sand the attention it requires beforehand. To give the casting a pleasing outward appearance, I would recommend always to work it with a sand jet blower.

# ABSTRACTS *

**No. 1. C. A Blast Furnace with a Continuous Flow of Metal.** A Bratke. " Stahl und Eisen," September 15 and October 1, 1903. Ill., 6700 w.— The difficulty of handling the enormous mass of iron produced each time a modern blast furnace is tapped has led to the introduction of various types of casting machines. In general these have not proved very successful on account of their complicated construction, and casting in sand is still the most commonly employed method.

The invention of Thos. Stapf, a director of the Ternitz Steel & Iron Works, Ternitz, in Lower Austria, patented in all important manufacturing countries, may perhaps overcome the difficulty. He removes both iron and slag as fast as formed automatically, continuously and separate from each other, and thus facilitates the subsequent handling. This object is attained by arranging at suitable heights in the hearth openings in such a manner that:

1. Slag cannot reach the tuyères.
2. The blast cannot escape.
3. Slag can pass only through the upper opening.
4. Metal can pass only through the lower opening.

The first condition is fulfilled by the mouth of the cinder notch being at a lower level than the tuyères. The second point is arranged for by the cinder notch sloping up toward the exterior, the height, $h_2$, Fig. 1, being arrived at by a simple calcula-

tion.   The third point is gained by making the exit of the iron notch sufficiently high above its entrance to insure that the column of molten metal shall counterbalance the slag and the pressure in the furnace.   The fourth point is assured if care is taken that $h_3$ is greater than $h_1$, Fig. 1.   Obviously, the iron notch should be placed as low down as possible.

That the new invention has practical advantages is proven by experiments made at the Trofaiach blast furnace by the in-
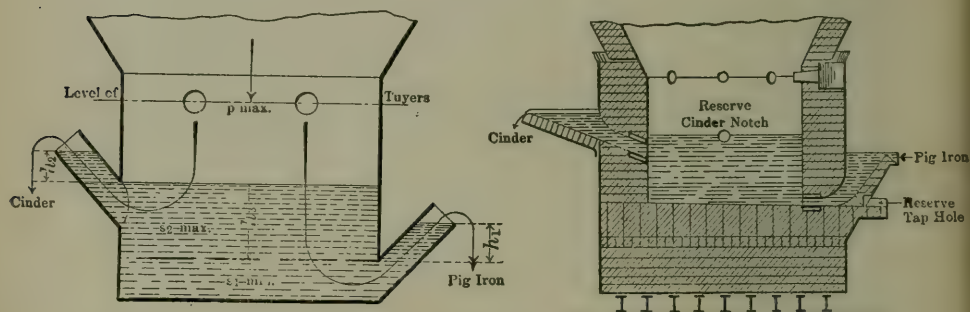


Fig. 1.   Arrangement for Continuous Flow.   Fig. 2. To Pig Casting Machine

ventor and A. Bratke of Trofaiach, Styria, who writes of the same in *Stahl und Eisen.*

The fact that the labor of breaking up the pig iron is done away with is in itself an enormous advantage.   Further, with the present system, on account of the tapping out periods getting out of time and the irregularity of the product, it is not easy to obtain for the steel works a sufficiently regular supply except by the use of an expensive metal mixer.   If the latter proves necessary with the new system it will be smaller, simpler and more compact than is now customary.

Further advantage is gained by the better working of the furnace when equipped with the new invention.   A furnace using the old method of tapping at intervals takes its burden in a very irregular manner, which in turn leads to hanging, slips and irregularity of product.   By using the continuous method these troubles would doubtless disappear, as the uninterrupted flow from beneath would cause an equally gradual movement throughout the furnace.   Further, the fact that the molten iron is removed as made, instead of standing for hours in the furnace, leads to a

decrease in the consumption of coke, an increase of production and greater regularity of quality. Owing to the possibility of sampling the metal at any minute, it is easier to counteract any . threatened disturbance. This fact alone makes this process valuable, even when, on account of the direct process being used, large quantities of molten metal are required at intervals, although in this case a mixer is necessary. Another gain is that it is unnecessary to slow down the engines when tapping or to blow out the iron notch afterward.

The principal advantage of the new method seems likely, however, to lie in the fact that all casting and loading machinery can be on a much smaller scale than formerly, owing to the same being in use continuously instead of at intervals, which fact will doubtless tend to overcome the prejudice existing among practical men against pig casting machines.

The method of carrying the new arrangement into practice will vary with local conditions. It will be advisable to make the slag opening large, by doing which easy access can be obtained to the interior of the furnace, and some of the advantages of the old style open furnace are regained. The openings for slag and metal should be opposite each other; firstly, to facilitate working around the same, and, secondly, in order to be able to reach the inside of the iron notch with a bar inserted in the slag opening.
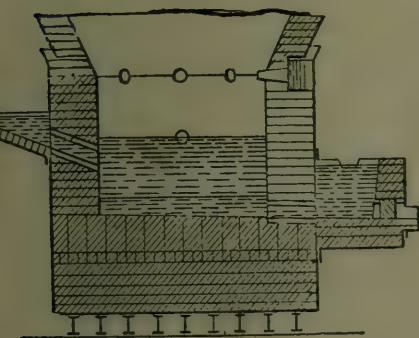


Fig. 3. Iron Forehearth.　　Fig. 4. Gas-Heated Iron Chamber.
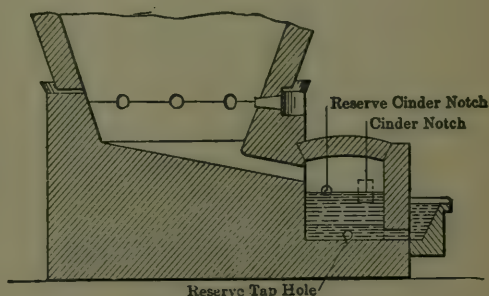
Iron and slag notches in the usual positions should be provided, so that all molten metal can be run off if desired and also in order that in case of need the furnace can be run in the usual

manner. This reserve tap hole is especially useful when blowing
in a furnace or restarting it after a prolonged period of inactivity,
as considerable uncertainty may exist at those times as to the
height of the molten materials within.    The latter is important,
because if the iron notch is opened before sufficient metal has
come down to allow the continuous flow to begin, the metal would
remain so long in the passage that great danger would exist of its
solidifying there.   In order to protect the brick work, it is advi-
sable to use water, cooled iron, or bronze blocks at the metal
and slag openings.

The sketches indicate sundry variations of the system to suit
varying conditions.   Fig. 2 shows the arrangement when the iron
flows from one side direct to the pig casting machine, while from
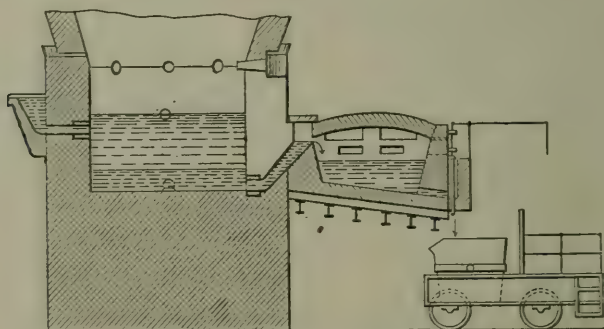


Fig. 5.   Continuous Flow Furnace.

the other the slag flows into the cinder cars.   Fig. 3 shows the
case where the iron notch is expanded into a small " fore hearth,"
whence the iron flows to the pig machine and from which also
small quantities can be tapped or dipped from time to time for
foundry or other purposes.   This arrangement is convenient when
it is desired to run off the metal in more than one direction.   Fig. 4
shows an arrangement whereby the metal flows into a gas-
heated chamber, whence it is taken as wanted for the steel works
or elsewhere.   In this chamber it may, if desired, be subjected to
a preliminary refining process.   Fig. 5 shows a continuous flow
furnace with the hearth as small as possible, for the double pur-
pose of diminishing the cooling surfaces and of removing the
molten metal rapidly.

From the above it may be seen that Stapf's patent may not

only be applied to new furnaces at a small cost, but may also be added to existing ones during a very short shutdown. The latter operation was carried out at the Trofaiach furnace, an old-fashioned stack producing some 30 to 35 tons a day, with very limited room at the base, and in spite of the adverse conditions it proved successful, although owing to the lack of experience and the bad condition of the furnace it was not possible to run the new method for long. The furnace is now being rebuilt, after which the experiments will be resumed, for which purpose the hearth is being arranged so that the iron flows to the left to the casting arrangement (run by one laborer), and the slag to the right, where it undergoes the process of granulation. The German author promises to publish the results of future experiments, regarding the successful outcome of which he professes to have no doubt.— " Iron Age," November 12, 1903.

No. 2. B. High-Speed Tool Steels. " Iron and Steel Trades Journal," October 31, 1903. 1800 w.— A joint committee consisting of members of the Council of the Manchester Association of Engineers and of members of the Manchester School of Technology Sub-Committee, together with Dr. J. T. Nicolson (Professor of mechanical engineering at the School), have just completed a long series of very valuable experiments. The purpose of the experiments was to test the capabilities of some of the high-speed tool steels that have recently been introduced. The report of the committee, embodying the results of the tests, was presented at the meeting of the Manchester Association of Engineers on Saturday evening.

The report is a voluminous document, including tables and illustrations showing the results of the trials.

Professor J. T. Nicolson, D. Sc., contributes to *The Manchester Guardian* the following outline of the work of the Committee :—

About three years ago an extensive series of experiments was undertaken by Messrs. Taylor and White at the Bethlehem Steel Works, Pa., U. S. A., in order to determine the data in question for various materials and to decide upon the tool steel best suited for their work. It was soon found that the results obtained from different tools made from the same steel varied greatly, and as the only way of accounting for this was by varia-

tions in the process of hardening, it was decided thoroughly to investigate this point. Up to this time all air-hardened steel had been invariably heated only up to a cherry-red temperature (about 1550° F.), and users were cautioned against heating beyond this before allowing the tool to cool gradually or in a blast of air. What Messrs. Taylor and White discovered was that when air-hardening steels are made with certain constituents in ascertained proportions they are greatly improved in their cutting efficiency by being heated to much higher temperatures than had ever before been tried in the process of hardening. They found that, although the steel appeared to be injured by heating to any temperature between 1550° and 1725° F., above the latter temperature and up to about 2000° F. (when the steel softens or crumbles when touched with a rod) the efficiency was greatly increased. If the greatest safe cutting speed for steel heated to cherry-red was 30 ft. per minute, then, when recourse was had to heating up to the " burning " point, the allowable speed would be increased to about 80 or 90 feet per minute. This discovery of Messrs. Taylor and White has proved to be the beginning of a new epoch in machine practice. It has brought about the running of machines at much higher efficiencies than have hitherto been thought possible, and by demanding closer speed regulation with greater range and a greater attention to the conditions governing power, strength and rigidity it has created a new era in machine-tool design.

A number of British firms have recently specialized in making similar brands of steel for rapid cutting, and it was with the object of testing the capabilities of such steels that the experiments in which I took part were undertaken.

The questions which the Committee set themselves to answer in these trials may be shortly stated as follows : — (1) What maximum speeds can be obtained with the new steels when taking light or finishing cuts upon hard, medium, and soft steel and upon hard, medium, and soft cast-iron? (2) What maximum area surface can be machined in a given time when taking a 3-16 inch cut with the new steels upon the six given materials? (3) What is the greatest weight of cuttings which the new steels can remove in a given time from the three grades of steel and the three qualities of cast-iron? (4) What forces are operative in making these cuts, and according to what laws do these forces vary in the speed of cutting and the area and shape of the cut?

(5) Can the new steels be forged and tempered by an ordinary smith and yet be relied upon to give results as to cutting, speed and durability which will make their adoption decidedly remunerative to steel users? In answer to the first question, it appeared that speeds of from 110 to 150 feet per minute were possible for soft steel, 80 to 110 for steel of medium hardness, and 40 to 50 for hard steel. In the case of cast-iron speeds of 100 to 110 for soft, 50 to 60 for medium, and 30 to 40 for hard were obtained. For comparison it may be mentioned that ordinary shop speeds for these materials with common brands of steel have been from 12 to 20 feet per minute. Question No. 2 may be briefly answered by saying that 45 square feet may be machined over in an hour by these rapid-cutting steels when operating upon soft steel with a cut 3-16 inch deep, the figures for medium and hard steel being 30 and 18 respectively. With cast-iron a surface of 42, 18, and 15 square feet may be turned off at the same cut in the case of the soft, medium, and hard varieties respectively. In reference to question No. 3, it may be remarked that but few specially heavy cuts were attempted; but it was found possible (when taking a cut ⅜ inch deep by ⅛ inch transverse) to remove 440 lbs., 330 lbs., and 180 lbs. of cuttings per hour from the soft, medium, and hard steel forgings respectively, and 450 lbs., 200 lbs., and 190 lbs. from the soft, medium and hard cast-iron specimens. In one instance, with a ⅜ inch by ⅜ inch cut cuttings were removed at the rate of 510 lbs. per hour from the soft steel bar. Inquiry may with propriety here be made as to the economy of making forgings so much too big that cuts so heavy as this have to be taken to bring them down to finished sizes. The answer is that it is found to be cheaper to forge roughly to shape and take off heavy cuttings in the lathe rather than to attempt close approximations to the ultimate dimensions of the piece under the hammer. The weights given above are from four to six times as great as can be removed with either ordinary water-hardened or ordinary Mushet tools. In reply to question No. 4, it was found that the forces acting upon the tool point when cutting were over 100 tons per square inch of area of section of cut in steel, and from 50 to 80 tons per square inch for cast-iron. This force is closely proportional to the area of the section (*i. e.*, the product of cut and traverse), irrespective of its shape, in both steel and cast iron.

One of the most noteworthy facts discovered is that the cutting force does not increase, but appears rather to diminish, with increasing speeds. This is contrary to the opinion generally held by turners and machine tool experts, as instanced by the objections raised by workmen to an increase of the cutting speed on account of the anticipated springing of the work. This objection can no longer be sustained, for although higher speeds of taking a given cut will of course require a greater driving power almost in direct proportion to the increased speed, no greater but rather a smaller force will be brought upon the tool, and the load acting on belts and gearing and the tendency of the lathe and work to spring will be rather diminished than otherwise. On the other hand, it has been conclusively shown by these trials that heavy cuts at moderately high speeds are much more economical in power than light cuts at the highest possible speeds the tool can stand. For the cutting speed does not increase as fast as the area of the cut diminishes, so that more material can be machined off in a given time with a heavy cut than with a light cut at its corresponding faster speed. Further, the total or gross horse-power required for cutting consists of the sum of that lost by friction of the intermediate gearing and of the lathe, as well as the effective work spent upon cutting. Now, the frictional power does not vary much, whether there is a heavy or a light cut on the machine; it therefore forms a much larger percentage of the whole at light cuts than at heavy cuts.

The value of the report is enhanced by the exhaustive tests of the physical and mechanical properties and the chemical constituents of the six different materials operated upon — namely, forged steel and cast-iron, each of three grades of hardness.

**No. 3. Iron Metallurgy in the Philippines.** H. D. Mc-Caskey. Abstracted from " Report on a Geological Reconnaissance of the Iron Region of Angat, in Bulacan." " Bulletin No. 3," The Mining Bureau, Manila, P. I.— The metallurgy of iron, as practised at present in the Philippines, is confined entirely to the province of Bulacan. At the time of my visit to the iron mines of Angat only one furnace was in blast, but a description of the methods used in its operation will suffice for all the other furnaces, as I have learned of no variation from the practice here.

The buildings in which the smelting is done are constructed

entirely of the products of the forests in the neighborhood. The posts and rafters are made from the trunks of trees; the pieces are secured in place by rattan, and no metal of any kind is used in the structure.

Preparatory to the erection of the smelter, the *maestro,* or foreman, assembles his assistants, and with them clears and levels the land selected for the smelter site, digs the clay from the stream banks, which is baked into bricks, erects the *camarin,* and prepares the molds, tuyères, slag-pots, and blowers. The *camarin,* once constructed, is divided roughly into three parts. One side is given up to little rooms, in which live the workmen, and where are stored the supplies and the furnace products, and another side is divided into ore-bins and charcoal-bins. The main central space is open and is used for the smelting operation proper. In the centre of the space are the two furnaces, with bamboo platforms at the sides upon which the feeders stand, with a tapping hole and slag runways at the front, and with the blower or air compressor and the connecting clay tuyères behind. Opposite the furnaces there is a row of molds placed in position for pouring immediately after the last castings have been dumped.

The furnaces are usually constructed of sun-baked fire-clay, the material being obtained from the decomposition of the crystalline feldspathic rocks of the neighboring hills. In some cases the bricks are molded and the furnace is built up of these; in other cases the furnace itself is molded as one piece, dried, and bound with rattan or iron. The thickness of the walls is so great that, notwithstanding the intense heat on the hearth during the smelting, the rattan is not burned off. In building the furnace a rectangular space 6 by 3 in. is left above the blow and tap holes, and into the latter are inserted blocks of a very silicious rock called *buga* by the natives. This word· is the Tagalo for pumice, and is a misnomer. The quartzose rock is quarried near La Mesa for this especial purpose, and the ironmasters pay two pesos for each block measuring 6 by 8 by 15 in. The principal function of these blocks, seemingly, is to furnish silica to the slag.

The hearth of the furnace is shallow and nearly circular. It is from 4 to 6 in. deep and about 2 ft. 4 in. in diameter. The total height of the furnace is 7 ft. 5 in., measured from the

ground, and the distance from bottom of hearth to top of furnace is 6 ft. An average section shows a thickness of the walls of about 1 ft., with a slight increase in thickness toward the hearth. The tuyère is a pipe, made from the best fire-clay, connected with a blower at one end, and passing through the furnace and opening upon the hearth at the other end. It is 2 ft. 7 in. long, 6 in. gross diameter, and with an inner diameter of 1.5 inch.
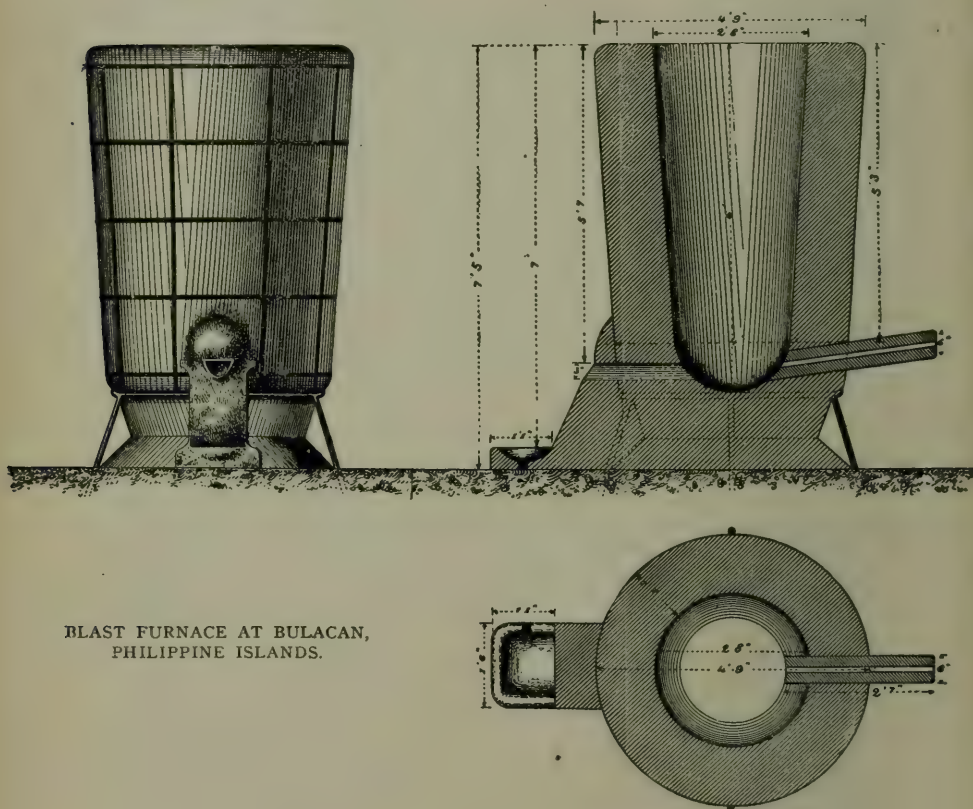
BLAST FURNACE AT BULACAN,
PHILIPPINE ISLANDS.

The air compressor, or blower, is as ingenious as it is interesting. It is made from the hollow cylindrical trunk of a *tanguile* tree, and is 9 ft. 8 in. long and 1 ft. 7 in. in its greatest diameter. One end of the blower rests upon the ground, while the other is supported by a cross-piece of wood. The ends of the blower are furnished with semicircular valves of leather

and wood, suspended from above, and closing by the pressure of air against them, when the piston moves forward. A separate piece of wood, serving for the compartment into which the air is forced, and from which it is driven through the tuyère end of the furnace, is fitted into the main blower and made air-tight. The connection between the tuyère and the air compartment is made by means of a short piece of cast iron tightly fitted. The piston is a circular piece of wood carrying on its perimeter a double row of feathers, while the piston rod is of *balite* wood, 15 ft. long and furnished with a double handle.

The molds used in the present operations are of two shapes and of variable sizes, suited to large, medium, and small castings. They are made of clay, carefully selected and ground, the bottom portions being shaped by pieces of wood cut in the desired patterns. The inner surfaces of the molds are freshly coated for each casting with a paint made of a mixture of bone-black, ground *palay* and water. The halves of the molds are placed in wooden frames, bound closely together with rattan and set upon a pair of forked sticks for the pouring.

The pouring-pot or ladle is made of fire-clay, bound with iron and furnished with a stout wooden handle. Its inner dimensions are about 8 in. and 6 in. for the larger and smaller diameters, and 6 in. deep. The few tools, such as pokers, ore-hammers and picks, are of wrought iron.

The ore, after mining, is carefully sorted and carried by *cargadores* to the smelter, where it is reduced to a uniform size of 1.5 in. diameter by means of a small hammer. The charcoal is burned by the laborers employed in the smelter and is of excellent quality. The degree of success attained by the native smelters depends largely upon the quality of the fuel.

Before the furnace is blown in, the hearth and body are filled with glowing fuel, the blower started, and the furnace is well dried and heated. The ore and fuel are then introduced alternately, the proportion at the beginning being one-half basket of ore to four baskets of fuel. After the furnace is well heated and the smelting operations are in full course, the charge consists of one full basket of ore to four of charcoal, and the furnace is kept filled, a cone of heaped charcoal being maintained on the top. The air compressor is worked at an average rate of 17 strokes per minute, furnishing ample pressure and

volume for the purpose. The process of reduction is comparatively simple, as the ore is self-fluxing and the fuel of high quality. The slagging of silica and alumina, with a certain proportion of the iron, takes place quickly, and the slag is drawn off every two or three minutes, when the furnace is under full headway.. Casts are made every two or three hours. The pouring-pot is filled, and the *maestro* passes down the line of molds, with the pot of molten metal, upon which floats a cover of burning charcoal. As rapidly as the castings harden the molds are opened, the castings removed, and the surfaces of the mold prepared for another pouring.

The products made in the smelters operating at present are plowshares and points, a share of the largest size weighing nearly 5 lbs. The castings are only of fair quality, and might be greatly improved. The prices obtained for the products vary with the season. During the months of May and June the entire output of the smelter is sold in the Angat district at the price of one peso per pair, that is, a plowshare and a point. During the other months a large part of the product is sent to Manila, where it is sold at the rate of from 70 to 90 pesos per 100 pairs. When the furnace is run steadily the output averages from 2000 to 3000 pairs a month.

The laborers required for operating one furnace are two *maestros,* or foremen, who have general charge; one *escribiente,* or clerk; two *escoradores,* or slagmen, who also act as molders; four *heladores,* or blowers, and from four to seven common laborers, who obtain and prepare the ore and fuel. They are paid according to the output of the furnace, the average wages for the entire force being about 60 pesos a month during the working season of four months, or about 40 pesos per month throughout the year.

It would seem that, if a market could be assured for a large output of castings, a modern furnace could be operated here at a handsome profit. The success of such an undertaking, however, would depend upon certain other conditions, such as supply of fuel, transportation costs and labor supply. I am inclined to the opinion that, on the whole, the conditions are favorable and that there is a future for the iron industry of the Philippines.— *Engineering and Mining Journal,* November 21, 1903.

**No. 4. B. The Relative Merits of Steel and Wrought Iron as Materials for Gas and Water Pipe.** "Engineering Magazine," November, 1903. 1200 w.— In a recent issue of "Engineering News" there appears a paper by Mr. Franklin Riffle, originally presented before the Pacific Coast Gas Association, upon the subject of commercial wrought iron and steel pipe, while in another portion of the same issue is a letter from Mr. John R. Freeman, the well-known hydraulic engineer, of Providence, R. I., discussing the same question from the point of view of the user; and both papers are of sufficient importance to be given more than passing notice.

The case in question at the present time is that of pipe for the conveyance of water and gas. The standard article for this service has been made of wrought iron to dimensions and grades which have been so well settled by usage as to be practically accepted as permanent. It now appears, however, that the manufacturers are producing large quantities of steel pipe, and according to Mr. Freeman are supplying it instead of wrought iron pipe.

Mr. Riffle, in his paper, to which reference has been made above, discusses the question openly from the standpoint of the manufacturers, and shows the advantages of steel as a material for pipe, in a detailed and definite manner.

So far as the strength and the resistance of steel pipe to corrosion are concerned, Mr. Riffle refers to the experiments of Professor H. M. Howe, which show the strength of the steel pipe to exceed that of wrought-iron pipe by amounts varying from 41 to 119 per cent, while so far as corrosion goes the tests made by Professor Howe show that there is no appreciable differences between steel and wrought iron.

Mr. Riffle still further adopts the position of the manufacturers when he advises the user to leave the question of specification to the maker, either accepting the product without limitations, or selecting from among the maker's specifications that which most nearly meets his requirements.

All this is eminently satisfactory, if the manufacturer may be considered as such an altruistic party as to select always the best for the customer, but Mr. Freeman evidently has views of his own upon this point. Thus, after stating that steel pipe is supplied in filling orders for wrought iron material, and that

the steel pipe runs from 5 to 15 per cent under the weight of standard wrought iron pipe of the specified dimensions, he goes on to say that the quality of material used in steel pipe is not of standard quality, but is skelp made of steel-works scrap, possessing none of the ordinary excellent qualities of mild steel as found in boiler plates and structural shapes. Under such circumstances Mr. Freeman suggests that further information is desirable upon the relative merits of iron and steel pipe, upon the relative strengths of existing pipe, upon the relative chemical composition of the material in steel pipe and that in structural steel and boiler plate, and upon the safe working strength of commercial pipe and fittings.

Accepting Mr. Freeman's position to the extent that it is most desirable that the truth in the matter be made public and that definite information concerning the vital points suggested be obtained, it may well be considered whether steel is not as superior to iron for pipe as it has been found superior to iron for other purposes. If the manufacturers put as good steel into pipe as they do into other products, and if every care is taken to insure toughness, perfect welds and general uniformity, there appears to be no good reason why steel should not be used, and many reasons why it should be favored.

At one time wrought iron rails were the rule, and steel rails the exception, but that day has long since passed, and wrought iron is no longer in the market for rails. The same transformation may be desirable for pipe, but the pipe must be proportionately as good as the rails or the change cannot be expected to meet the approval of that careful and reliable class of engineers so well represented by Mr. Freeman.

**No. 5. Sorbitic Steel Rails.** "Engineering News," September 24, 1903. The inferior wearing qualities of steel rails produced at the high temperatures necessitated by the rapid rolling of modern rail mills has for some years been and is yet a vital matter to railway engineers in America. For some years the slogan of these consumers has been — a lower finishing temperature! The rail manufacturers have on their part spent large sums of money to meet this demand without reducing the output of their mills. To what extent they have succeeded in this task we need not consider here. Searching in another direction for

the same object, a better wearing rail, some railways have struck upon nickel steel, and are conducting tests of nickel steel rails at large cost. That railways are even considering for rails a material of such cost and one, moreover, whose cost is bound to increase upon any large demand for it because of the limited amount of nickel available for alloying purposes, indicates the pressing nature of the demand for more durable rails. In view of these facts the announcement made by Messrs. Stead and Richards in their interesting paper [before the Iron and Steel Institute] that by a very simple heat treatment the life of steel rails can be increased from 25 to 50 per cent is a most important one.

In metallurgical language this increased durability is secured by the substitution of sorbite for a portion of the pearlite in the steel. To bring about this substitution it is only necessary to quench the heads of the rails to a certain temperature and allow the residual heat to temper the steel by the slow cooling of the rail. The process is in plain terms a simple hardening and tempering process. Accepting as a fact that this hardening and tempering process will perform all that is claimed, the question arises whether it can be successfully applied to rails with the rapidity with which they are produced by modern rail mills. Messrs. Stead and Richards state that they have not yet an affirmative answer to this question, although they hope to have one before long. It is in this item of practical manufacture that the new discovery, if we can so call it, is certain, it seems to us, to encounter the greatest obstacle to its useful application in rail making.

**No. 6. A. Standards for Buying Foundry Iron.** Dr. R. Moldenke. " The Foundry," October, 1903. 1500 w.— The author calls attention to the work of the Committee on Cast Iron at the Delaware Water Gap meeting of the American Society for Testing Materials. On Mr. Colby's motion it was resolved that " in all contracts where foundry pig iron is sold by chemical analysis, each car load, or its equivalent (in case of ship loads) shall be considered a unit, and in said car load at least each two tons of iron shall be represented by a pig, said pig to be selected at random so as to represent fairly the car load of iron. Drillings shall be taken so as to represent fairly

the fracture surface of each pig, and the sample analyzed shall consist of an equal quantity of drillings from each pig, well mixed and ground before analysis." No specifications have yet been adopted with regard to the drilling of the pigs. The next clause says that, " In the absence of a definite understanding to the contrary, a variation of 10 per cent of silicon either way and of 0.01 in sulphur above the standard is allowed. A deficiency of over 10 per cent up to 20 per cent in the silicon, and a further increase in sulphur up to 0.01 over the above allowance subjects the shipment to a penalty of 1 per cent in the price for each element so affected.

The report further says, " In the absence of specifications, the following numbers thrown to the trade, will represent the offended analysis per standard grades, irrespective of the fracture :

| Grade | Per cent silicon | Per cent sulphur |
|-------|------------------|------------------|
| No. 1. | 2.75 | 0.035 |
| No. 2. | 2.25 | 0.045 |
| No. 3. | 1.75 | 0.055 |
| No. 4. | 1.25 | 0.065 |

These analyses are subject to the same allowances and penalties as given further above."

The final outcome of this earnest endeavor to simplify an organic trade trouble is being watched with great interest. If a success, which all indications point to, such a benefit will come to the foundry and furnace, that an immense stride in the economic life of the nation will have been taken.

**No. 7. Tests of Steel for Electric Conductivity, with Special Reference to Conductor Rails.** J. A. Capp. American Institute of Mining Engineers, October, 1903. 4900 w.— What is required is sufficient surface for the collection of the powerful current and an ample cross-section to carry the current without an undue drop in potential. On the other hand, the strength of the section is of little moment, and any section which is easily installed in an insulator is satisfactory. This permits the use of sections, rectangular or nearly so, which may be rolled easily in many mills. With these facts in mind a section of a conductor rail has been designed by W. B. Potter which, when 2.5 inches wide by 4 inches high, will weigh about 98 pounds to the yard. This shape may be easily

rolled in any merchant bar mill heavy enough to attempt sections of this weight. A dovetail at the bottom provides an easy means of securing the rails by fish plates of special forms, and any of the common forms of bond may easily be applied. Ordered in lots of a thousand tons or more, such a rail should cost no more than a plain rectangle of equal weight.

From the elaborate tests on the influence of special additions to steel upon its electric conductivity it appears that manganese preponderates in influencing the resistance of the steel, and that for lowest resistance manganese must be present in very small quantities, much smaller than is usual in merchant steel or structural steel. While all the elements must be present only in very small percentages, so great is the preponderance in the influence of manganese that other elements may be tolerated in quantities which the steel makers would consider reasonable without unduly increasing the resistance.

For a satisfactory third rail the lowest possible resistance (say, from 6 to 6.5 times that of copper) is not necessary, and the great cost of making such extremely pure steel is not warranted. In fact, such extremely pure steels would probably be so soft that the frictional wear of the collecting shoe would be excessive and the life of the rail in service unduly short. Assuming, then, that a rail made from steel having a resistance not greater than eight times that of copper (13.8 microhms at 20° C.) would be desirable for conductor rails, the figures tabulated would seem to indicate that the following extreme composition would be permissible:

| | Per cent |
|---|---|
| Carbon up to | 0.2 |
| Manganese up to | 0.4 |
| Phosphorus up to | 0.06 |
| Sulphur up to | 0.06 |
| Silicon up to | 0.05 |

This composition, however, would be extreme, and any overstepping of bounds might result in too great resistance; therefore, for resistance up to eight times that of copper, the specified analysis should be:

| | Per cent |
|---|---|
| Carbon not to exceed | 0.15 |
| Manganese not to exceed | 0.30 |
| Phosphorus not to exceed | 0.06 |
| Sulphur not to exceed | 0.06 |
| Silicon not to exceed | 0.05 |

This latter composition is one which could be made easily in any open-hearth furnace, and it should present no difficulty in rolling to a shape suitable for conductor rails. In fact, steel of this composition has been successfully rolled into sheets as thin as 0.014 inches, a size, which was for a long time a standard product of a large sheet mill.

Mr. Capp added some remarks concerning wear and tear of such conductor rails, and from what he said it appears that this is a very serious question. While he did not give the exact figures, he said that the wear and tear of the third rail of the Manhattan Railroad has been about 1-10 inch since the time of its installation. — " The Iron Age," October 29, 1903.

**No. 8.   A.   Salisbury Steel & Iron Co.'s Steel Tie.** " Iron Trade Review," October 29, 1903. Ill., 400 w.— The Salisbury Steel & Iron Co., of Utica, N. Y., closed negotiations last week for the general assignment to the company of the Knox patents for steel railroad ties. The Knox tie has been carefully examined by several prominent railway officials and engineers and is found to have several advantages without the disadvantages embodied in some designs of steel ties. It is simple
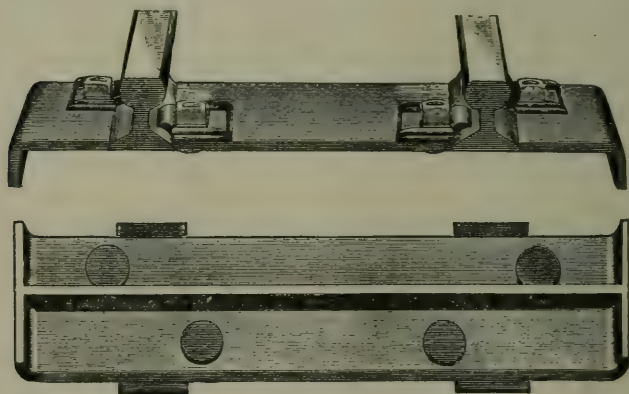
The Knox Rolled or Cast Steel Cross Tie.

in construction, consisting of a cast T shape of open-hearth steel the top of which is about 10 inches wide, 8 feet long, $\frac{5}{8}$-inch thick. The flange extends the whole length of the

under side, in the center, and is joined to a cross-piece at each end, both the central under-flange and the ends being 4 inches deep, and of the same thickness as the top plate. The rails are held in place by steel clips, which are in turn bolted to the tie. Among the advantages claimed for the Knox tie are the ease with which it can be tamped from either side; the anchorage made by the central flange and the ends, preventing the tie sliding in any direction on the roadbed; the central flange stiffening the upper plate sufficiently to support the heaviest loads without injury to the tie or rolling stock; also increased ductility.

**No. 9. B. Open-Hearth Steel Making and Blast-Furnace Gas in Gas Engine.** Peter Eyerman. A paper read before the Civil Engineers' Club of Cleveland, September 22, 1903. "Journal of the Association of Engineering Societies," September, 1903. 6250 w.— In spite of the many labor-saving appliances which have been introduced in the manufacture of open-hearth steel, the cost of this metal has not been cheapened enough to compete with Bessemer steel. The author looks toward the employment of blast-furnace gas instead of producer gas as the most promising means of effecting a material reduction in the cost of production. In his opinion the blast furnace of the future will be more important as a producer of gas than of pig iron. He describes some charging appliances desirable to meet the requirements of the blast furnace considered as a gas producer. The author describes a "compound furnace," which consists of an open-hearth furnace heated by blast-furnace gas with arrangement for firing by the air blast. He argues, from calculations, that open-hearth or "compound" steel can be produced under good conditions just as cheaply as pig iron to-day or still cheaper in connection with the modern gas engine.

**No. 10. B. Alumino-Thermics.** By Hans Goldschmidt. "Electrochemical Industry," November, 1903. Ill., 6900 w.— The author describes, with many illustrations, the application of thermit to the following purposes: Production of pure metals free from carbon, welding, repairing of castings, welding of wrought iron tubes and solid rods, production of ingots free from pipe. This last application of thermit is thus described by the author:

" The thermit process as used for this purpose consists in in-troducing a box of so-called anti-piping thermit into the block with the aid of an iron rod, in exactly the same way as described before. According to the size of the block, the box is suspended about one meter (3.3 feet) (Fig. 2).   The reaction is completed in this case



Fig. 1.    Steel Block show-ing defective head (piping), without use of thermit.
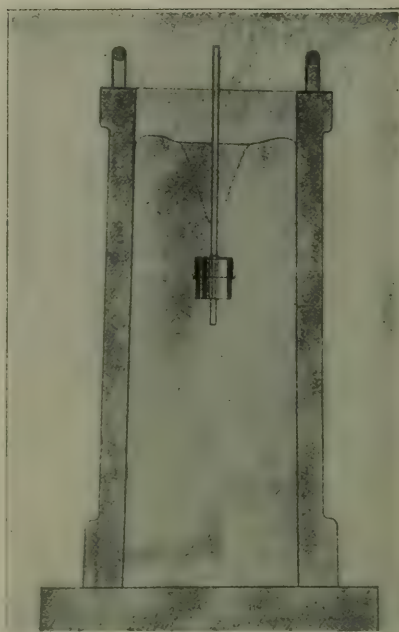
Fig. 2.    Steel Block with box of anti-piping thermit im-mersed.
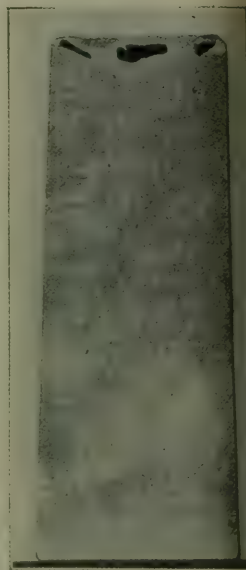
Fig. 3.    10-Ton Steel Bl after having been trea with anti-piping thermi

in a few seconds.   The box is introduced, of course, only after the piping has been formed, that is, after about 15 to 20 minutes.   The head layer, which has already become solid, is broken through for this purpose.   Immediately after the reaction is completed, steel, which had been kept prepared for this purpose, is poured into the open hole.   The method is really very simple, and one learns very quickly at which time to introduce the box.   Moreover, the method is very cheap, only about 5 kilograms of thermit being required for blocks of 10 to 20 tons of weight.   In Fig. 1 is shown a block cast without the use of thermit, while in Fig. 3 is seen a block which had

been treated by the method of Mr. Mathesius. After the treatment relatively very small pores were found, and only in the upper part of the block as shown in the illustration, so that the loss was only very few per cent. The method has also been applied for very large steel castings to revive steel which had become plastic in the runners."

The author concludes as follows, " While the thermit methods have found a very extended application and rapid development in most European countries, and have also been applied in some foreign countries, especially for making repairs, it is surprising that they have been used in practice to a comparatively very small extent in the United States. While the metals free from carbon, especially pure chromium, have found here a ready market, yet the welding of rails by the thermit process, which should be of the greatest importance to this country has not yet been tried.

" This may be due to the fact that the keynote of the industrial development of the United States is specialization, while the thermit methods are of a very manifold nature, as was shown in this article. The production of pure chromium, etc., is of importance for the steel industries. In view of the many uses of manganese, free from carbon, the thermit process should become equally important for the manufacture of alloys of copper, nickel, and bronzes. But besides these metallurgical applications, the thermit process is useful in various mechanical operations, for making repairs of all kinds, for instance, in railroad repair shops, in machine factories, and especially in the navy. The field of welding wrought iron tubes may be considered again as a separate one. Finally, by the use of anti-piping thermit for improving castings, a further successful field has been opened.

" On account of these reasons the introduction of thermit and its applications has been behindhand in the United States. The author hopes, however, to be shortly in a position of establishing a suitable organization in this country which will enable the introduction of the various applications of thermit into general use. In view of the engineering talents of the American people, it may be expected that the thermit methods will find a special wide application in this country after a suitable beginning has once been made."

**No. 11. A. The Addition of Silicon in the Basic Process for Steel Castings.** W. E. Mumford. " American

Manufacturer and Iron World," November 5, 1903. 900 w.— The writer recounts the difficulties and losses incident to the addition of silicon, in the basic process and describes the method used by him for overcoming the objections as follows: "Arrange a small cupola whose bed approaches as nearly as possible the amount of furnace additions to be used. The whole amount of additions to be melted down and drawn at one tap. As soon as the furnace man finds his heat of steel nearing completion, the blast is put on at the cupola and the charge melted down and drawn off into a small ladle which is taken to the open-hearth furnace and held over the large ladle in readiness for the tapping of the steel.

" Assuming the chemist has found the steel free from phosphorus, a tap is made and the molten additions allowed to run into the large ladle, while not more than one-half the steel has run out from the furnace.

" By the time the slag has come, the steel has absorbed the silicon and manganese and there is no further action on the slag. I have found it advisable to melt about one-half of the ferro-manganese to be used in the cupola with the ferro-silicon and the other half I run through the furnace in the usual way. This quiets the metal and gives better results than if the metal were boiling and also gives a smaller loss of silicon.

" If this method of molten additions is carefully manipulated there need be little loss of silicon and the use of aluminium will never be found necessary."

**No. 12. C. A New Method for Preventing Piping in Steel Ingots.** J. Riemer. " Stahl und Eisen," November 1, 1903. Ill., 3000 w. — To prevent piping in steel ingots a new method has been advanced, which does not involve compressing the ingot during solidification. The principle of the method is to allow for the escape of the gases in the steel, and for the necessary shrinkage during solidification, by keeping the upper part of the ingot in a fluid condition until after the larger part of the ingot has solidified. To accomplish this, a burner cap is placed on the top of the ingot mold, and a gas blast-flame is directed downward upon the metal in the mold; vent-holes at the sides of the cap provide for the escape of the gases. The flame is so proportioned as to keep the upper part of the ingot

considerably above the melting temperature, thereby causing the ingot to solidify progressively upward. The metal can thus follow the contraction in volume and the gases in the metal can freely escape. Sections taken from ingots cast with the use of this method show a very small depth of honeycombing at the top, and uniformly sound metal below this. The crop-end can be reduced to less than 10 per cent of the ingot by this means. The gas and air supplied to the burner must be preheated so as to produce the highest possible flame-temperature. The cost of using this method is said to be very low. The method has been patented by a German, Mr. J. Riemer. It is described more at length in a recent number of "Stahl und Eisen." — "Engineering News," November 19, 1903.

**No. 13. C. Metallography in the Service of Metallurgy.** E. Heyn. A lecture delivered at the 5th International Congress of Applied Chemistry, Section of Metallurgy, Berlin. Ill., 12,900 w. "Craz and Gerlach, Freiberg.— The author says in the preface: "In spite of the fact that the beginnings of metallographical knowledge was due especially to Martens, a German, it is unfortunately a fact, which cannot be passed over in silence, that activity in this field is very much less in our own country than in foreign countries, especially in France, England, America, and Russia." We can only assent to the complaint expressed in this sentence, and greet with pleasure the fact that the author, widely known in the field of metallography, has taken it upon himself to foster the interest in metallographical research, and to offer for a wider circle a clear explanation both as to its usefulness in metallurgy and in other applied sciences. The book mentioned above serves this purpose. It contains the substance of a lecture which the author gave at the 5th International Congress for Applied Chemistry, Section of Metallurgy, at Berlin.

In order to make intelligible to the reader who is not familiar with this subject the theory of the solidification and melting of the metallic alloys, Heyn proceeds from the simple and easily proved example of a solution of common salt in water, and then applies the laws thus discovered to the metallic alloys, which as is known, in the fluid condition, are considered as solutions. Among the alloys cited, those of lead and silver ought especially to excite the

interest of metallurgists, because, upon the separation of the lead crystals that are poor in silver from the mother-liquor rich in silver, as is known, the Pattinson process rests. This, according to the experiments of the writer, is not to be looked upon as a single phenomenon in the series of metallurgical processes, but is considered as the representative of a great group of separation processes. For iron metallurgists, naturally the iron-carbon alloys form the most important part of the treatise. Heyn compares them in so far as they deal with the transformation of substances already solid to the type of the salt and water solution, while he explains the solidification of fluid iron by the help of the phenomena of solidification observed in the melting of nitrates of potassium and sodium. Finally the theory of the puddling process is treated metallographically.

We cannot complete our review of the foregoing book without expressing from our point of view the regret that the iron-carbon alloys have not received a more comprehensive treatment. This is naturally explained by the fact that Heyn's address was made before an audience of chemists and not one of iron metallurgists. It is hoped that the author will undertake a supplementary exposition with this purpose in view, devoted to a special exposition of the application of metallography to iron metallurgy.— "Stahl und Eisen," October 15, 1903.

**No. 14. A. Nickel Steel for Locomotives.** "The Locomotive Magazine," October 3, 1903. 175 w.— A locomotive is now under construction at the Baldwin works, for the Canadian Copper Co., of Sudbury, of which the boiler plates are of nickel steel, and the same material is being used for the frames, axles, crank-pins, piston rods, etc., etc. The cost will be somewhat increased, but a considerable gain is expected from the reduced wear and tear, and longer life.

**No. 15. A. A Record Breaking Casting.** "The Iron Age," October 22, 1903. Ill., 180 w.— The author describes in an illustrated article what is said to be the largest casting ever made in this or any other country. It consists of an engine bed cast by the Wm. Tod Company, of Youngstown, Ohio, for the Lackawanna Steel Co. of Buffalo. The casting measures 33

feet 5 inches in length by 12 feet 1½ inches in width, and weighs, cleaned, 168,000 pounds.

**No. 16. B. Notes on the Microstructure of Steel.** James E. Howard. "Iron and Steel Trades Journal," November 14, 1903. 2500 w.— The author's speculations as to the value of the microscope leads him to the following inference: "In conclusion it is not thought that the subject of metallography is in that state in which the microscope may be implicitly used for the accurate determination or recognition of those physical properties in iron and steel which give strength and safety to engineering structures." The imparting of such precise information cannot, of course, be claimed by any method of testing and probably never will.

**No. 17. C. Manganese Ore as Desulphurizer in the Cupola.** F. Wüst. "Stahl und Eisen," October 15, 1903. 1500 w.— An article containing an account of experiments carried out for about half a year in order to test the desulphurizing effect of manganese ore in the cupola. A number of analyses of the pig iron before and after using manganese ore are given, and it appears from them that in the ordinary process of melting the pig the average sulphur content of the casting was .111 of 1 per cent, while the addition of manganese ore brought it down to .064 of 1 per cent. The addition of manganese ore was made in the proportion of 5 kilograms (11 pounds) of ore to 600 kilograms (1,323 pounds) pig iron, and 36 to 38 kilograms (72.4 to 83.8 pounds) coke plus 6 kilograms (13.2 pounds) limestone.— "Mines and Minerals," December, 1903.

**No. 18. Measurement of High Temperature.** From a lecture by Mr. H. Wanner.— As early as February, 1900, a description of a new method for measuring high temperature was published, which permits, at least for a certain group of glowing bodies, the measurement up to the highest temperatures. When a compact body is heated, the rays emanating from same may be observed by the human eye, the body's color will change with the rising temperature from dark red to light red, to yellow and to bright white,

which means, that at first mainly red rays are observed to which at the higher temperature the other spectrum colors, orange, yellow, etc., are added until the rays appear white. In analyzing the rays by a prism it is found that with the rise of temperature some single color, for instance, red, suffers a rise in the intensity which can be measured progressively with a specially constructed photometer. By knowing the law which combines mathematically the acting factors: the temperature, the proper light-intensity of a single color, and its wave length, makes it possible to measure unlimited high temperatures by the photometric measurement of the light-intensity of a certain color, as explained in the above principle.

The apparatus to be applied is therefore a photometer containing at the same time a prism to separate a single color. Let it be simply stated, that a spectrum is created in the ordinary manner by a slit, lenses, and a straight vision prism, from which, by a diaphragm, light of a certain wave length is excluded, and the measurement of the light intensity is made by polarization. To that part of the apparatus facing the radiation to be examined, a small incandescent lamp is attached, the light of which passes through that part of the apparatus, which is used for comparing the intensity to be measured. On looking through the apparatus one observes the circular field of vision, divided into two halves, (same as in a ½ shade sugar testing polariscope) one of which is illuminated by the small incandescent lamp, the other by the light of the glowing body being examined, both halves of the field show red color. On turning the eye-piece containing the Nicol's prism both halves of the field of vision can be easily brought to even intensity, and by turning the attached divided circle the amount of degrees are measured. The actual temperature found is given by a table accompanying each instrument, which temperature has been calculated by means of the law mentioned before. The method should be regarded as follows: The electric comparison lamp is omitting rays of a known temperature with which the unknown temperature is being compared. The entire procedure is so simple that it can be readily learned by any foreman or intelligent workman within a short time. The whole apparatus is 30 c/m long (12″), built like a telescope and can be easily handled without a support. It does not matter how great the distance is from which the measurements are taken, if only the field of vision is properly

illuminated by the light emanating from the body to be examined.

By actual experiments I obtained for blast-furnace slag 1321° C., for outpouring iron 1384° C., for slag pouring from the converter 1700° C. The temperature of the converter gases seemed to remain below 1500° C. The radiation of the flame, however, causes a rise of temperature as decarburation, etc., progresses. The falling of the temperature, during scrap addition can be measured progressively, while the absolute temperatures could not be obtained on account of the constant changeable transparency of the flame. The temperature of flowing steel can only be measured by looking directly upon the same.

The advantage of this new apparatus consists in its reliability, because its indications are based on a law of Nature scientifically and correctly determined, and not an empirical one; on its accuracy; its exceeding handiness; on the fact that it may be used with or without support; on its portability and its quick adjustment (consuming, according to experience, but a few seconds). The instruments may be adjusted at the start to any desired temparature, thus showing exactly when the same is reached. Another special advantage of the apparatus is that it can be trained upon any visible part of the furnace in order to compare the temperature in different places in the furnace. The instrument may be obtained from Eimer and Amend, New York.

**No. 19. The Development of the Bessemer Process for Small Charges.** Bradley Stoughton, American Institute of Mining Engineers, 1903. Ill., 30,000 w.— Reviews the various small Bessemer vessels and their working and describes a long tuyère converter recently designed by the author for Benjamin Atha & Co., of Newark, N. J.

**No. 20. A. Case-Hardening, with Special Reference to Locomotive Work.** Paper read by A. W. McCaslin before the Buffalo meeting of the National Railroad Blacksmiths' Association at Buffalo, N. Y., August, 1903. — A short description of the process of case-hardening materials and of the results obtained. "Railway Machinery," October, 1903. 2600 w.

**No. 21. A. The Chemistry and Physics of Cast Iron in**

the Light of Recent Knowledge. J. E. Johnson, Jr., "American Machinist," October 8 and October 15, 1903. 6000 w.

**No. 22. A. Nickel Steel: Its Properties and Applications.** Albert Ladd Colby. A paper read before the American Society for Testing Materials. Abstracted in "Engineering and Mining Journal," October 10, 1903. 4700 w.

**No. 23. C. Experiments on the Firing of Crucible Furnaces.** F. Wüst. "Stahl und Eisen," October 15, 1903. Ill., 1500 w.— The author gives a detailed account of experiments conducted at Aachen, Germany, under his direction and concludes that there is no economy in operating crucible furnaces with preheated air.

**No. 24. A. The La Belle Iron Works.** "The Iron Age," October 8, 1903. Ill., 4700 w.— A full and illustrated description of the La Belle Iron Works, at Steubenville, Ohio.

**No. 25. B. Borsig's Works in Germany.** "Engineering," October 9, 23, 30. Ill., 8900 w.— A very excellent and complete account of the company's plant at Borsigwerk, in Upper Silesia, from its beginning in 1837 to the present day. The article includes numerous plans and illustrations.

An account of the Tegel works of the Borsig Company will appear in subsequent issues of "Engineering."

**No. 26. A. Steel Castings and the Tropenas Process.** By Arthur Simonson. Read at the meeting of the New England Foundrymen's Association, Boston, October 14, 1903. Abstracted in "Iron Trade Review," October 29, 1903. 3600 w.— An able description of the production of steel castings with special reference to the Tropenas process.

**No. 27. A. New Steel Plants and Merchant Bar Mills of the International Harvester Co.,** at South Chicago, Ill. Full illustrated description. "The Iron Trade Review," October 15, 1903. 5800 w.

**No. 28. A. The Relative Hardness of American and European Cast Iron.** J. E. Johnson, Jr. "American Machinist," October 22, 1903. 1100 w.

**No. 29. A. Modernizing a Large Foundry.** "The Iron Age," October 22, 1903. 3000 w.— Describes the recent enlargement and improvement of Maher and Flockhart at Newark, N. J.

**No. 30. A. A Suggestion for a Test of the Effect of Silicon in Neutralizing Sulphur in Cast Iron.** J. E. Johnson, Jr. "American Machinist," October 29, 1903. 1000 w.

**No. 31. A. The Foundry and Town of Trafford City, Pa.** "Engineering Record," October 31, 1903. Ill., 3800 w. — A very interesting and complete description of the efforts of the Westinghouse interests to unify their foundry properties, resulting in the establishment of the works and industrial town of Trafford City.

**No. 32. B. On the Manufacture of Ferro-Alloys in General and of Ferro-Titanium in Particular, in the Electric Furnace.** Auguste J. Rossi. "Electrochemical Industry," November, 1903. 4100 w.

**No. 33. A. The American Tube and Stamping Co.'s Steel Plant at Bridgeport, Conn.** "Iron Age," November 5, 1903. Ill., 3000 w.

**No. 34. A. Annealing.** E. R. Markham. "American Machinist," November 5, 1903. 1500 w. — The author describes what he considers the best method of annealing grades of steel.

**No. 35. A. The New Foundry and Pattern Departments of the B. F. Sturtevant Co., at Hyde Park, Mass.** "Iron Trade Review," November 5, 1903. Ill., 3600 w. — A comprehensive description of the new plant, with plans and illustrations.

**No. 36. A. New Blast Furnace Plant of the Toledo Furnace Co.,** " Iron Trade Review," November 5, 1903. Ill., 3000 w. — A very comprehensive and excellent description, containing numerous plans and double page illustration.

**No. 37. B. Fractures and Characteristics of Iron and Steel.** R. B. Griswold. " Power," November, 1903. Ill., 2700 w. — An elementary article dealing with the fracture, composition, and properties of wrought iron, steel, and cast iron.

**No. 38. B. Tensile Tests of Mild Steel and the Relation of Elongation to the Size of the Test Bars.** Professor W. C. Unwin, B. S. C., F. R. S., M. Inst. C. E. A paper read before Institution of Civil Engineers, London, November 10, 1903. " Iron and Steel Trades Journal," November 21, 1903. 700 w.

**No. 39. B. American Methods in the Steel Trade.** H. J. Waddie. West of Scotland Iron and Steel Institute. — A critical essay on the difference between the management of American steel mills and those of Great Britain. " Iron and Steel Trades Journal," November 14, 21, 28, 1903. 6700 w.

**No. 40. A. Preventing Pipes and Blow Holes in Ingots and Castings.** Dr. F. C. Weber. " Iron Age," November 12, 1903. 1800 w. — The writer describes the use of metallic oxides in combination with titanium alloys for the prevention of " pipes " and blow holes in ingots and castings.

**No. 41. A. The Bottom of a Green Sand Mold.** Thomas D. West. A paper read at the New England Foundrymen's Association, Boston, November 11, 1903. — An important article, in which the author discusses the various difficulties connected with the making of green sand molds and suggests a systematic plan of procedure with a view to overcoming them. " Iron Trade Review," November 12, 1903. 4300 w.

**No. 42. A. The Top of a Green Sand Mold.** Thomas D. West. A paper read at the New England Foundrymen's Association, Boston, November 11, 1903. — The author discusses many features of a green sand mold, such as gaggers and

soldiers, dampness of sand in the surface of copes, "drawing down" and skin-dried copes, density of sand in rammed copes, venting and vent wires, open and closed risers. "Iron Trade Review," November 19, 1903. Ill., 4400 w.

**No. 43. A. Economy in Buying, Mixing, and Melting Iron.** Herbert E. Field. "Iron Trade Review," November, 12, 1903. 5800 w. — The author discusses at length the economy of buying, mixing, and melting iron.

**No. 44. A. Blast Furnace Conditions and the Composition of Foundry Iron.** Paper read by Mr. W. Walley Davis at the Milwaukee meeting of the American Foundrymen's Association. "Journal of the American Foundrymen's Association," June, 1903. 3000 w. — The author describes the working of the blast furnace and the influence of the character of the burden, the temperature and the nature of the slag upon the composition of the resulting cast iron.

**No. 45. A. Thermit in the Foundry.** Dr. Hans Goldschmidt, of Essen. In the course of a very well-attended and successful lecture at Columbia College, New York, on "Alumino-Thermics," the inventor gave some interesting data on the use of "thermit" in the iron and steel foundry. The substance of the lecture is given in the "Iron Age" for November 19, 1903. 1800 w.

**No. 46. A. Blast Furnaces and Steel Plant of the Clairton Steel Co., at Clairton, Pa.** A comprehensive description of the plants and processes. "Iron Trade Review." November 19, 1903. Ill., 4400 w.

**No. 47. A. Non-Corrosive Nickel Steel Boiler Tubes.** Albert Ladd Colby. Paper read before the eleventh general meeting of the Society of Naval Architects and Marine Engineers, New York, November 19, 1903. — The author discusses ably the non-corrosive character of nickel steel boiler tubes. "Railroad Gazette," November 20, 1903. 2300 w.

# EDITORIAL COMMENT

Henry Marion Howe    The photograph of some eminent iron and steel Metallurgist accompanied by a biographical sketch will appear in every issue of *The Iron and Steel Metallurgist*, and it is eminently fitting that Henry M. Howe should have been selected for this initial number.

Henry Marion Howe was born in Boston in 1848, the son of Dr. Samuel G. Howe and of Julia Ward Howe, whose names the world over suggest the highest moral, intellectual and civic attainments. He graduated from Harvard College in 1869, and from the Massachusetts Institute of Technology in 1871. He then studied the manufacture of steel at the Bessemer Steel Works, at Troy, N. Y., where he learned to carry out with his own hands the more important operations connected with the making and working up of iron and steel. In 1872 he assumed the duties of superintendent of the Bessemer Steel Works at Joliet, Ill., now owned by the Illinois Steel Company. From the time he left the Massachusetts Institute of Technology until 1883 he was actively engaged in metallurgical manufacture, chiefly that of iron and steel.

In 1877, Mr. Howe undertook an important mission to Chile in connection with copper smelting, and during the period from 1880 to 1882 he designed and built the works of the Orford Nickel and Copper Company at Capelton, Canada, and at Bergen Point, N. J. From 1883 to 1897 he resided in Boston, engaged as a consulting metallurgist and an expert in metallurgical patent cases, being also a lecturer on metallurgy at the Massachusetts Institute of Technology.

In 1897 he was offered the chair of metallurgy at Columbia University at New York, which he accepted and now occupies.

At the Paris Exposition in 1889 he was a juror in the class

of "Mining and Metallurgical Processes," and in 1893 he was president of the jury on " Mines and Mining " at the World's Columbian Exposition.

Professor Howe is a member of many scientific and technical societies, being a past president of the American Institute of Mining Engineers, which office he held during the International Engineering Congress which met at Chicago in 1893. He is a member of the American Academy of Arts and Sciences, and a non-resident member of the American Philosophical Society, of Philadelphia, an honor paid only to scientists of high attainments.

His writings are too many to be enumerated here, for he has enriched metallurgical literature with about a hundred papers and memoirs, all of them valuable, some of them classical. In 1890 appeared, in book form, his treatise on " The Metallurgy of Steel," a monumental work, which called forth the admiration of the metallurgical world, and which will forever testify to the magnitude of the intellectual power of its author.

His writings, crowned by this masterly production, brought him speedy recognition by the scientific societies of the world, among which stand foremost the award of the Bessemer gold medal, — the highest distinction to which a metallurgist may aspire, and which was presented to him in 1895. On the occasion of the presentation of the medal to Professor Howe, Professor Roberts-Austen said in part, that he [Professor Howe] had done for the literature of metallurgy what his own countrymen, Emerson, Hawthorne, and Lowell, had done for English literature generally, — to produce a work which might form a part of, and enter into the daily occupations of, their life."

The French " Société d'Encouragement pour l'Industrie Nationale " awarded to Professor Howe a prize of 2500 francs.

The German Society for the Promotion of Industry presented to Professor Howe its gold medal, — the highest distinction which it can bestow upon a foreigner; the Franklin Institute of Philadelphia also presented to him its highest award, the Elliot Cresson gold medal. In 1901 he was created a Knight of the Legion of Honor by the French government.

In 1902 Professor Howe published his little book entitled " Metallurgical Laboratory Notes," the first attempt ever made to describe a comprehensive laboratory course for students of

Metallurgy. More recently (1903) his important work, " Iron, Steel, and Other Alloys," has appeared, a fitting companion to his " Metallurgy of Steel." Professor Howe is now in Europe, this being his sabbatical year, and we are given to understand that he is actively engaged in further literary work. The metallurgical world will always await with keen interest any contributions from his masterly pen.

**Iron and Steel Alloys**
The alloying with iron of such elements as nickel, manganese, tungsten, chromium, etc., has resulted in the production of metals possessed of properties so valuable that new applications are found for them almost daily, while the introduction of high speed tool-steel, so brilliantly originated by Messrs. Taylor and White, is revolutionizing our machine shop practice. Few Metallurgists, if any, have done more to advance our knowledge of these important alloys than Mr. R. A. Hadfield, the distinguished manager of the Hecla Works of Sheffield, England, and inventor of Hadfield manganese steel. The series of papers on iron and steel alloys which he has contributed to the Iron and Steel Institute constitutes a most valuable and authoritative treatise of the production and properties of these metals, and entitles their author to the gratitude of the metallurgical world.

In the present issue we publish an article by Mr. Hadfield which we believe will be read with great interest and profit by our readers, since it is not only an excellent summary of our present knowledge of the subject, but contains some valuable data now published for the first time.

**Tar as an Open-Hearth Fuel**
The untiring efforts of Metallurgists in advancing their art has yielded no more important and significant results than the great reduction in the cost of production which has taken place during the last twenty years. If we were to inquire into the causes which have led to this most gratifying result we would find that they are chiefly of two kinds: (1) the introduction of labor saving appliances, and (2) a better utilization of waste products. In an article published elsewhere in this issue Mr. David Baker, a steel Metallurgist of high repute, suggests a means of decreasing the cost of open-hearth steel, which belongs to the second class,

describing as it does the burning, in the open hearth furnace, of the tar resulting from the distillation of coal in coke ovens. While the author takes pains to show that at the present time it is only under especially favorable conditions that such procedure will prove economical, his paper will be found suggestive and may lead others to investigate the merits of this new departure.

**The Presence of Iron Oxide in Cast Iron** The objectionable or even disastrous effect caused by a small amount of oxide of iron in steel is known even by those who possess only a rudimentary knowledge of steel metallurgy. Indeed, the presence of this substance in Bessemer steel at the end of the blow came near causing the abandonment of the Bessemer process at an early stage of its existence. Dr. Moldenke, an expert in cast iron of universal reputation, tells us elsewhere in this issue that cast iron may be similarly afflicted and he shows that the remedy usually applied to steel, namely, the addition of Spiegel-eisen or ferro-manganese, is not here available or at least effective. The presence of an appreciable amount of iron oxide in an iron bath containing so much carbon may be a source of surprise to some Metallurgists, but since the statement comes from so authoritative a source, the matter should receive the careful attention of those interested in the betterment of cast iron castings.

**The Vitality of the Puddling Furnace** A decade ago the iron trade was looking for the obituary of the puddling furnace. Eleven years ago an editorial was printed in a leading technical journal describing the patient as in a bad way. A careful compilation had been made, showing the decrease in the number of puddling furnaces during the previous year. A few years later the basic open-hearth process sprung into sudden prominence in the United States and threatened to kill the patient, if it did not die of senility, by providing a new and extensive market for scrap.

Yet the puddling furnace, and by it we mean to include scrapping, busheling, etc., furnaces, still lives. There are no accurate statistics, but a careful estimate indicates that rolled forms of iron outside of steel in the United States in 1902 amounted to about a million tons, as compared with a million and a quarter

tons in 1892. A comparatively small part of this outside tonnage consisted of material where the operation consisted only of piling or rerolling, such as the rerolling of old rails. The bulk of it consisted of forge pig and iron and steel scrap, put through the processes of puddling, busheling, etc.

The rolling of this product requires much more skill than the rolling of soft steel, and involves the use of small mills where the current charges are much higher, per ton of output, than in the large mills used for rolling steel, and it is somewhat curious that this industry has survived, when it would appear that the pig and scrap process in the basic open-hearth furnace should afford a more economic means of utilizing the scrap, besides possessing the advantage of a comparatively homogeneous product, which the iron coming from the puddling furnace is not.

Even when, in the early part of 1903, the market price of common iron merchant bars, made principally from scrap, rose to several dollars a ton above the price of soft steel merchant bars, the consumption was not seriously interfered with. Many small consumers adhere to iron because of the greater ease of welding, while a prominent railroad corporation returned during the year to the use of iron for certain car parts, believing that greater safety lay in its use. In this case of course the iron is manufactured under rigid rules. The ordinary " common iron " of commerce is subject to practically no limitations whatever on the part of the buyer, and is not even as uniform in section as its steel counterpart.

**The Rolling of Ornamental Shapes**    There is a line of rolling iron which with one exception is so far as we know unpractised in the United States, although it is quite an industry in Germany. We refer to the rolling of shapes where there is a recurring pattern, the section varying periodically. The product is used mainly for architectural ornamentation, and may combine utility with ornamentation, as in a handrail, or may be purely ornamental and unnecessary structurally.

The Germans issue elaborate catalogues of this product, containing hundreds of engravings of different patterns, ranging from perhaps an inch to a foot in width. The price averages from three to five cents a pound. The Germans use charcoal iron, their steel at least being unsuited to filling in the pattern.

The plain section is rolled with several passes and a heavy draft, while the pattern is impressed in a single pass in a two-high mill with pinions, working at a very low speed. The roll on the pattern side is cast in sand from a wooden pattern, some tool work being necessary.

Floor plate, of extremely simple design, is the only shape we know of involving a periodically varying section, which has been rolled in the United States. With the growth of artistic sense in this country there should be a greater demand for such a product as the Germans use, but the want could perhaps be as well filled by chill castings or stamped sheet metal.

# CORRESPONDENCE

## On the Simultaneous Presence of Ferrite and Cementite in Steel

*To the Editors.*

SIRS : — Referring to your article on the " Simultaneous Presence of Ferrite and Cementite in Steel " in the April, 1903, number of *The Metallographist,* this simultaneous appearance of both components, side by side, is theoretically possible, and easily understood if we take into consideration the Phase rule. According to the Phase rule, we have

$$F + r = n + 2$$
$$r = n + 2 - F$$

in which F represents the degree of liberty, $n$ the number of components present, and $r$ the number of phases.

In the system Iron-Carbon, we have two components ($n = 2$) and, because we consider the system hitherto constant under tration. We have consequently for constant pressure, only two atmospheric pressure, $F = 2$ — namely, Temperature and Concen- phases ($r = 2$), side by side, unlike. For example : at a higher temperature, ferrite and martensite, or martensite and cementite. At a particular temperature (also for constant pressure and constant temperature) we have only one degree of liberty ($F = 1$), and then three phases can occur side by side. This is the case at $A_1$ where we find side by side three phases, martensite, ferrite, and cementite.

Pearlite is not (as Roozeboom has already rightly pointed out) a single phase. It consists of two phases, ferrite and cementite, and, if the material is kept long at $A_1$, *i. e.,* if the change takes place very slowly, then, according to the known principle of slow crystallization, alternate plates of ferrite and cementite will not be formed (*i. e.,* pearlite will not occur) ; but ferrite and cementite will be segregated in large masses (structurally free), and thus occur side by side.     HANNS JÜPTNER VON JONSTORFF.

Unterburg, Germany, Oct. 5, 1903.

## Abnormal Structure in Brass

*To the Editors.*

SIRS: — I enclose a photomicrograph that I took in Dum Dum of a piece of cartridge brass.

Can you possibly throw any light on the subject, as to why it should occur? The contrast is very marked indeed. Frequently of late I have had these specimens to examine; in some cases,
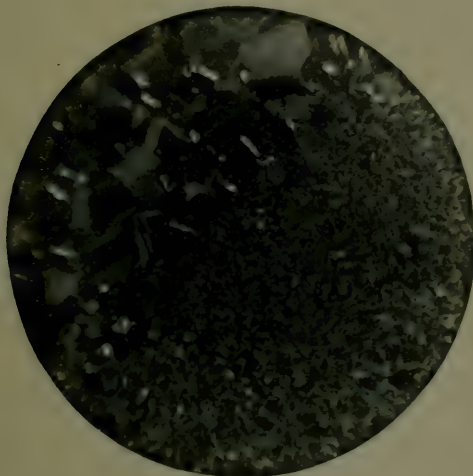


0.70 per cent Cu, 0.30 per cent Zn, magnified 42 diameters.

there are streams of these fine crystals running through clusters of large crystals; they are of a copperish color. When etched electrolytically these fine streams develop " pits " and present a spongy appearance. When etched with dilute $HNO_3$ the surface is perfectly even.

I should be glad if any of your contributors could throw light on this phenomenon.

J. W. VARLEY.

London, Oct. 31, 1903.

# IRON AND STEEL METALLURGICAL NOTES

**The Coming American Meeting of the Iron and Steel Institute.** — The secretary has issued the following circular under date of October, 1904.

At the conclusion of the General Meeting at Barrow-in-Furness, Mr. Charles Kirchhoff, of New York, tendered, on behalf of the American Members of the Iron and Steel Institute, an invitation to the Institute to hold its next Autumn Meeting in New York. This invitation, which was endorsed by the American Institute of Mining Engineers, the American Society of Mechanical Engineers, the American Institute of Electrical Engineers, the Franklin Institute, and the American Foundry-men's Association, was, on the motion of the President, accepted by the general meeting with acclamation.

It is proposed that the Autumn Meeting shall take place in New York on October 24, 25 and 26, 1904. After the meeting there will be an excursion to Philadelphia, Washington, Pittsburgh, Cleveland, Niagara Falls, and Buffalo, returning to New York on November 10. During the trip night traveling will be avoided, and every endeavor will be made to obviate fatigue. The two Sundays will be spent at Washington and at Niagara Falls. The approximate cost of the stay in the United States is estimated at £25.

For the convenience of members desirous of visiting the St. Louis Exhibition, arrangements will be made for a limited number to leave Pittsburgh for St. Louis and Chicago, reaching New York on the evening of November 10. This trip will necessitate three nights being spent in sleeping cars, and the approximate cost will be £35.

In order to carry on negotiations with the principal steamship companies so as to obtain for members the advantages of reduced rates, it is necessary to know as soon as possible the probable number of members who propose attending the meeting.

I should be obliged, therefore, if you would kindly fill in the enclosed card and return it to me at your earliest convenience.

———————————

**Steel Works Records.** — We summarize below a few cases in 1903 where iron and steel works have broken their own previous records. While not vouching for the accuracy of the figures in all cases, we believe them to be substantially correct.

*Converting Departments.* — Shenango Valley Works at New Castle of Carnegie Steel Company; two 10-ton vessels, increased from 8-ton in 1902, using direct metal; on March 24, in 24 hours, 2133 gross tons of ingots were produced.

Edgar Thomson Works of Carnegie Steel Company; four 15-ton vessels, of which one is always kept off for lining and repairs; mixer metal; during October (27 working days) blew 6116 heats, which would be an average of one in 19 minutes for each of three converters; product was 88,068 tons of ingots, equal to 12½ tons per heat.

*Rolling Departments.* — Buhl Works, Sharon, of Carnegie Steel Company; six 30-ton basic open-hearth furnaces; 35-inch blooming, three-high 27-inch finishing mill and 24-inch bull head; in 11 hours in March rolled 410 gross tons billets; previous record for 12 hours, 395 tons; record for 24 hours, 710 tons.

Shenango Valley Works; double tandem mill, 12 trains of two stands each, one line for billets and one for sheet bars, 406 feet from first to last stand, all stands not always used; in 24 hours in March exceeded 1600 tons of billets and sheet bars.

Edgar Thomson Works; in October (27 working days) three-high 40-inch blooming mill made 76,519 tons blooms; 27-inch rail train made 55,388 tons standard rails; 23-inch rail train made 15,056 tons, of which 5000 tons were light rails; total of two mills, 79,444 tons. On October 29 the two mills made 2939 tons of rails.

South Works, South Chicago, Illinois Steel Company; three 12-ton vessels, three-high 40-inch blooming mill, rail mill of four three-high 27-inch stands; in October rolled 67,000 gross tons rails.

**The Republic Iron and Steel Co.** — Anent various vague reports that the Republic Iron & Steel Company proposes to add

a rail mill to its Bessemer plant at Youngstown, O., it is of interest to recall the character of the present plant. When originally set up, in 1900, the plant utilized machinery from the Alexandria, Ind., and Springfield, Ill., plants of the company, at each of which there were two old 5-ton vessels. Two of these were set up as 6-ton vessels, together with the 32-inch blooming mills of the Alexandria works. Two years ago a new billet mill was added. Last summer the old vessels were replaced with new standard 10-ton vessels, and the 32-inch blooming mill was replaced by a new 40-inch blooming mill. The new billet mill just referred to is really three mills: a 26-inch billet mill, an 18-inch small billet mill, and a slabbing or bar mill, to roll thin bars. The billet mill consists of three stands of 26-inch two-high rolls, the center one direct and the others by gears. The bloom passes continuously through the first and third, and through the second on its return. Rolling 4-inch billets, the 7½-inch bloom moves forward, receiving two passes, backward receiving one, and forward receiving two. For 3-inch billets an additional round trip, back and forth, is given. If smaller billets are desired, the piece passes to the 18-inch continuous mill, having four stands, with passes to roll 1½, 1¾, 2 and 2¼ inch billets. The slabbing or bar mill consists of two stands of rolls, beside the 26-inch mill, driven from the two outside stands, there being placed beyond a bull head, with a rope drive. It is apparent from this description that the billet mill will not lend itself to conversion into a rail mill, as was done at the Ohio plant of the National Steel Company, by the mere addition of a rail finishing department and changing rolls in the former billet and sheet-bar mill.

**The Lackawanna Steel Co.** — The Lackawanna Steel Company, Buffalo, N. Y., has placed a contract with the Morgan Construction Company, Worcester, Mass., for a continuous merchant bar mill. While details of the mill are not available, it is stated that in a general way it will resemble the Duquesne merchant bar mill. This latter is the finest in the world, and has been in operation only a little over a year. It is of unusually massive construction, all the passes being practically bull heads, and the furnaces are placed close to the mills, so that the front ends of the 30-foot billets have received four roughing passes before the rear end has left the furnace.

It is a twin mill, each side having four continuous roughing stands and six finishing stands. On the 13-inch side the finishing stands are in two trains of three, and on the 10-inch side in three trains of two. On the heavier side there are automatic repeaters and on the lighter hand-finishing is employed. The cooling beds are each 450 feet long.

**Blast Furnaces at New Castle, Pa.** — No. 2 of the New Castle, Pa., furnaces of the Carnegie Steel Company is being torn down to be replaced by a modern stack. Ultimately the company will have four thoroughly modern furnaces in the New Castle group. As assembled by the National Steel Company, formed in 1899, there were the old Shenango stack, of the Shenango Valley Steel Company, the Neshannock stack, purchased by the company, and the Rosena, purchased by the National Steel Company from the Oliver & Snyder Steel Company. The National Steel Company built a fourth, designated No. 4, which ranks the highest in the world, being $106\frac{1}{2} \times 23$ feet, blown in during July, 1901. The rebuilding of No. 3 is nearly completed. No. 2 is now to be rebuilt to duplicate No. 4. No. 1 is to be relined and improved. Being now $100 \times 20$, it is not desirable to rebuild it. Nos. 2 and 3 were both $75 \times 18\frac{1}{2}$. There has been some talk of building a fifth furnace, but nothing has crystallized regarding it.

**The Rhenish Westphalian Coal Syndicate.** — The fact that the prolongation of the Rhenish Westphalian coal syndicate as well as of the pig-iron syndicate has been assured is one of the most important events connected with the German iron and steel industry of the present year. It assures a sound basis for the further development of the industry. If the exertions tending to the formation of the steel syndicate should also prove to be successful the German iron and steel industry can rely on a powerful factor for maintaining the steadiness of the whole market. The regulations drawn up for the steel syndicate provide that the individual works shall furnish their share of the general output as desired, both as regards territory and quality of the product. By this means a more systematic distribution of labor and output will be obtained, an advantage already possessed by the American trusts. The new syndicate, therefore, will represent an intermediate form of association between a German Kartell and an American trust.

**The Technical University at Aachen.** — Great interest is taken in Rhenish Westphalian iron circles in the development of the Technical University at Aachen, which town, owing to its favorable location near the German iron-making centers — Rhenish Westphalia and Lorraine — seems to be the most suitable place for cultivating the science of the metallurgy of iron. Clearly realizing these conditions, the Verein Deutscher Eisenhüttenleute submitted a petition to the Prussian Government urging the establishment of special facilities for the scientific education of iron Metallurgists and offered a sum of 100,000 marks to further the above-mentioned purpose. In addition to this contribution additional amounts were raised, and the erection of a new and imposing building was begun. That the university has already proved to be a fertile soil for the investigation of problems connected with the metallurgy of iron, may be seen from the series of papers presented by Professor Wüst to the Association of German Iron Foundries.

**The New Blast-Furnace Plant at Porto Ferrajo, on the Island of Elba.** — The plant comprises two coke blast furnaces, with a daily minimum production of 150 tons each. The coking plant consists of 104 Coppée ovens, with a capacity of 4.2 tons each. The daily production of the whole plant amounts to 310 to 325 tons of coke. The waste gases of the first 20 ovens are used for firing three boilers. The coke has to be quenched with sea water, other water not being available in sufficient quantity. In spite of its high percentage of salt the coke has caused no trouble in the working of the furnace. The blast-furnace plant includes seven stoves. The arrangement is such that all of the stoves can be connected to each of the two furnaces. The blast furnace operates very satisfactorily, notwithstanding that 45 per cent of fine ores are smelted. The consumption of coke amounts to 900 kg. per ton of iron. The normal burden for hematite pig iron is 7,500 kg. of ore, 2,100 kg. of lime, and 400 kg. of coke; for foundry pig, 7,500 kg. of ore, 1,920 kg. of lime, and 4,000 kg. of coke.

The blowing plant consists of two Delamarre-Cockerill gas blowing engines, driven by the waste gases of the blast furnace. Their dimensions are: Diameter of gas cylinder, 1.3 meter; of blowing cylinder, 1.7 meter; length of stroke, 1.4 meter. Moreover, there is a reserve steam blowing engine.

# FINANCIAL REVIEW

We devote the space allotted to the monthly financial review and forecast to a brief summary of iron and steel market history in 1903.

The American iron and steel trade is never uninteresting. Every year stands out with distinctive and novel features. While there are great cycles of movement, covering ten and twenty-year periods, the events in them are so framed that until they have passed into history they are seldom recognized as repetitions. Thus the year 1903 was one of constantly declining activity, with steady lowering of prices in many lines, a movement quite closely paralleling the one which started only a few months more than twenty years earlier. As the decline of 1882-3 followed the boom started in 1879, which in turn was an awakening from the severe depression in 1873, so the present decline followed the boom of 1899, which marked the sudden change from the bad years from 1893 to 1898. The parallelism is astonishing in its exactness, yet true to its habits, the iron trade at the beginning of the year had finely wrought arguments to convince the most devoted worshipers of the cycles that there was a new era in which conditions would prevent history from repeating itself.

At the beginning of 1903 the iron trade may be likened to a building in which the lower floors had ample factors of safety for their working loads, while a few upper floors were weak. Finished steel products were not unreasonably high; they were much lower than the high points reached in 1899. Pig iron and billets were unduly high. The prediction was that they would recede until they reached a proper parity with finished steel lines, and there the whole structure would be secure. But while the upper floors of our structure were in process of being strengthened, they gave way, and being precipitated on the lower floors, only strong enough for their own loads, serious damage was done to the whole building, so that at the close of the year some look

askance at the whole structure, while the engineers are debating whether there will be further casualties, or whether the edifice can be quickly restored to its old-time usefulness.

At the opening of the year Bessemer pig iron was $21.50, valley, or $22.35, Pittsburg, and firm for any first half delivery, steel works being well covered and blast-furnaces well sold up. Billets were scarce and so high as to be available only for special purposes: from $31 to $33 at mill. It involved a loss to buy them for conversion into any of the heavy finished lines. Imports of German Thomas steel had not ceased. Rails were $28, and plates and shapes $1.60, the same prices which had been established in April, 1901. Merchant steel bars were $1.60, a price which had been made effective April 1, 1902, after large consumers and jobbers had been permitted to enter annual contracts at the previous price of $1.50. Here lay an important weakness; as these contracts expired during 1903, the buyers were called upon to make new contracts at an advance of $2.00 a ton, when current conditions did not warrant an advance. Probably the steel mills would have been only too glad had it been possible to blot out their action of a year previous, but a retrograde movement was impossible, because it would have acted to impair confidence.

In the lighter lines, wire, pipe, sheets and tin plate, the trade was at the beginning of the year just recovering from the effect of the drastic cuts which had been made in the fall of 1902, these lines having been disproportionately high, and having been cut from $5 to $10 a ton at intervals. Sheets had been cut openly $5 a ton, to $2.75 for black and $3.85 for galvanized, 28 gauge, and quietly special concessions were made to large buyers. These were gradually withdrawn, being emergency measures, and when, by the first of April, the actual market had risen to the nominal market, an appearance of strength was given which was not real. The movement in wire also tended to becloud the real situation. An advance of $1 a ton was announced January 2, and a further advance of $2 on February 23, making plain wire $1.90 base and wire nails $2.00 base. These advances, however, were dictated not by the general strength of the market, but by the absorption of the Union-Sharon wire plants by the steel corporation. It had been largely their competition which had forced the drastic cuts the preceding fall.

A further and more important barrier to a disclosure of

whatever unsoundness there was in the position in the opening months of the year was the railroad blockade, which started in the previous fall with the rush to move ore and coal before the close of lake navigation, and when this work was done, was continued by the advent of untoward weather. Furnaces secured coke only with the greatest difficulty in the winter; one furnace ran but three days in a month; from a fourth to a third of the central western furnaces were banked for days at a time. Whenever the railroad situation eased up, demands from the east, growing out of the anthracite strike prevented an improvement in coke receipts in the west. Suddenly, with the advent of spring weather, the railroad blockade was lifted, coke dropped from its absurd prices, ranging from $5 to $8 at ovens for spot furnace, and $7 to $15 for spot foundry, pig iron production increased, and furnacemen began to be disturbed. May showed a production of over 1¾ million tons of pig iron, a figure which had never been approached by a hundred thousand tons, and probably will not be for some time.

From that time to the end of the year the decline in the market has been marked and continuous. Space is not at command to chronicle its details.

What 1904 has in store for the iron trade no one can tell, but it is pretty certain that we have had a depression only, and have not entered upon such a lean period as we had from 1893 to 1898. General conditions warrant nothing of the sort. The worst is probably over, but how soon the improvement will come is another question. Prices of pig iron cannot recede much further. In the south they have already turned, cost having been reached. In the territory tributary to the Lake Superior ores cost has been reached, and the effect of lower coke and lower wages with the new year has been discounted. Ore prices may or may not be reduced; even should they be, the blast-furnace industry cannot be expected to discount the fact. The 27½ millions of lake ore brought down in 1902, and the 24 millions in 1903 will last furnaces well through the summer. It must all be paid for at the 1903 season price. In finished material we may have some price changes here and there, but they are not likely to be important in either direction. The export trade will gradually be increased from its already comfortable proportions.

# STATISTICS

**The World's Production of Pig Iron and Steel.** — It is fitting, on the establishment of a magazine devoted to the metallurgy and metallography of iron and steel, that the tonnage extent of the field should be surveyed, particularly since a tabular statement of the output of the different countries shows how eminently fitting it is that such a magazine should issue from the United States.

Several compilations of the world's output of pig iron and steel have been made at various times. On account of the slowness with which the statistics of some countries are collected or made public, such compilations have covered a comparatively remote year. To the present, none at all has been made for the calendar 1902, and it is necessary even at this time to assume that the production of some countries was identical for 1901 and 1902. While the metric ton of 2,204.6 pounds is undoubtedly the logical standard for such an international comparison, especially since the official returns of all countries except the United States, Canada and the United Kingdom are so expressed, one shrinks from doing the violence of converting the production of the two greatest producing countries of the world from the standard with which they are familiar and with which they transact their regular business. Our table, therefore, employs the gross ton of 2,240 pounds. This explanation can hardly be considered unnecessary, in view of the fact that all such compilations which we have seen have been hybrids, in which metric and long tons are added together indiscriminately. The difference between the two tons is greater than the possible error of such estimates as must be made.

### World's Production of Pig Iron and Steel in 1902, Tons of 2,240 lbs.

|  | Pig Iron | Steel Ingots and Castings |
|---|---|---|
| United States . . . . . . . . . . . . . . | 17,821,307 | 14,947,250 |
| United Kingdom . . . . . . . . . . . . | 8,517,693 | 5,000,000* |
| Germany and Luxemburg . . . . . . . . . | 8,269,700 | 6,710,000† |
| France . . . . . ~ . . . . . . . . . . | 2,389,000 | 1,500,000‡ |
| Belgium . . . . . . . . . . . . . . | 1,053,000 | 750,000‡ |
| Sweden . . . . . . . . . . . . . . | 516,110 | 279,200 |
| All other countries. . . . . . . . . . . . | 5,008,190 | 3,558,550 |
|  | 43,575,000 | 32,745,000 |

\* Estimated from official figures of Bessemer and open-hearth ingots only.  † Estimated.
‡ Estimated from rolled steel total.

Among " all other countries " are included Austria-Hungary, Russia and Finland, Spain, Italy, Canada, Mexico, etc. The important countries among these are not given separately because their production in 1901 only is available, and it is assumed that there has been no change.

Approximate figures of production by decades since 1850, for which we do not vouch, are as follows :

|      | Pig Iron    | Steel       |
|------|-------------|-------------|
| 1850 | 4,400,000   | 85,000      |
| 1860 | 7,400,000   | 200,000     |
| 1870 | 11,900,000  | 700,000     |
| 1880 | 17,950,000  | 4,274,000   |
| 1890 | 27,150,000  | 12,231,000  |

It is hardly necessary to point out that the rise in steel production from insignificant proportions a half century ago merely represents the rise of processes for making a product which is, largely for convenience, called " steel." The wrought iron of half a century ago was from a commercial standpoint the counterpart of the soft steel of to-day. And it should be borne in mind also that even so lately as 1850 figures of pig iron production are not an accurate index to the consumption of iron, since the product of the Catalan forge was even then of commercial importance. Some years ago Mr. James M. Swank estimated the production of pig iron in 1800 at 825,000 tons, but this was no index to the production of *iron,* nor is any such obtainable.

The year 1903 will show an increase over the above figures. While production in the United States fell off greatly towards the end of the year, the heavy production in the first six months had given a good lead over 1902, and the year may show a production of 18,300,000 tons. Germany showed a gain in the first half of 870,000 tons ; it is possible therefore that these two countries, producing in 1902 60 per cent of the world's total, may show a combined increase of some 2,200,000 tons, so that the world's production of pig iron in the year just closed may lie in the neighborhood of 46,000,000 tons, and of steel ingots and steel castings in the neighborhood of 35,000,000 tons.

**Imports and Exports of Manufactures of Iron and Steel.** — The following table, recently compiled by the Bureau of

Statistics of the Department of Commerce and Labor, gives the value of imports and exports of manufactures of iron and steel since the year 1820:

| Years | | Imports | Exports |
|---|---|---|---|
| 1820 | . . . . . . . . . | —————— | $46,552 |
| 1830 | . . . . . . . . | $6,316,237 | 322,747 |
| 1840 | . . . . . . . . | 8,192,093 | 1,127,877 |
| 1850 | . . . . . . . . | 17,665,398 | 1,953,702 |
| 1860 | . . . . . . . . | 21,526,594 | 5,870,114 |
| 1870 | . . . . . . . . | 32,665,454 | 13,483,163 |
| 1880 | . . . . . . . . | 53,714,008 | 14,716,524 |
| 1890 | . . . . . . . . | 41,679,591 | 25,542,208 |
| 1900 | . . . . . . . . | 20,478,728 | 121,913,548 |
| 1902 | . . . . . . . . | 27,180,247 | 98,522,562 |
| 1903 | . . . . . . . . | 51,617,312 | 96,642,467 |

The decrease in exportation since 1900 is evidently due to a greater home demand, as evidenced by the fact that the production of iron and steel has steadily increased during that period at the rate of some 2,000,000 tons yearly.

The exports in 1900 were divided geographically as follows:

| | |
|---|---|
| Europe . . . . . . . . . . . . . | $45,788,554 |
| North America . . . . . . . . . | 42,378,119 |
| South America . . . . . . . . . | 7,357,417 |
| Asia . . . . . . . . . . . . . . | 11,225,144 |
| Oceania . . . . . . . . . . . . | 12,869,947 |
| Africa . . . . . . . . . . . . . | 2,304,498 |

The iron and steel products exported in 1900, the year of our largest exportation, may be divided in round numbers as follows, in their order of importance:

| | |
|---|---|
| Machinery of all kinds, wholly or chiefly of iron or steel, | $75,000,000 |
| Locks, hinges, and other builders' hardware, . . . . . | 6,000,000 |
| Wire . . . . . . . . . . . . . . . . . . . | 5,000,000 |
| Pipes and fittings, . . . . . . . . . . . . . . . | 5,000,000 |
| Steel rails, . . . . . . . . . . . . . . . . . | 5,000,000 |
| Tools, . . . . . . . . . . . . . . . . . . | 3,000,000 |
| Boilers and parts of engines, . . . . . . . . . | 2,000,000 |
| Castings, . . . . . . . . . . . . . . . . . | 1,500,000 |

Other articles ranging downwards in their relative value are: Wire nails, firearms, pig iron, steel bars, stoves and ranges, bar iron, steel sheets and plates, wire rods, saws, cut nails, iron sheets and plates, tacks, scrap iron, cutlery, safes, car wheels, tin plates, hoop, band and scroll-iron billets, ingots and blooms, and iron rails.

**Iron and Steel Production in Russia.** — According to the *Moniteur des Intérêts Matériels* the iron and steel production of Russia in the years 1900 and 1902 was as follows, the figures representing metric tons :

|      | Pig Iron  | Iron and Steel |
|------|-----------|----------------|
| 1900 | 2,882,880 | 1,998,360      |
| 1902 | 2,555,240 | 1,949,220      |

The depression in the Russian iron industry indicated by these reduced productions began in 1899, but the publication cited sees many signs of an early recovery.

**Production of Manganese in the Caucasus.** — The production of manganese ore in the Caucasus has been as follows during the last eight years :

|      | Output            | Export            |
|------|-------------------|-------------------|
| 1895 | 118,077 metric tons | 165,550 metric tons |
| 1896 | 158,988    "      | 144,269    "      |
| 1897 | 198,718    "      | 178,537    "      |
| 1898 | 266,325    "      | 239,326    "      |
| 1899 | 557,778    "      | 394,079    "      |
| 1900 | 661,153    "      | 419,420    "      |
| 1901 | 418,827    "      | 337,457    "      |
| 1902 | 408,571    "      | 440,433    "      |

In addition to these amounts about 65,520 metric tons are yearly obtained from the district of Nicopol government, Tekaterinoslaw, and about 1,638 metric tons from the Ural. The ore body in the Caucasus range is estimated to contain 98,280,000, that in the Nicopol district 40,950,000 metric tons. The figures for the Ural range are not known. Although the export of Caucasian manganese ore has risen last year by 110,876 metric tons, that is, 32 per cent, the mining industry there severely suffers from overproduction. The total production of ferro-manganese in Southern Russia amounted to :

|                | 1901             | 1902             |
|----------------|------------------|------------------|
| Spiegeleisen   | 39,312 metric tons | 49,140 metric tons |
| Ferro-manganese | 14,742    "      | 24,570    "      |
|                | 54,054           | 73,710           |

# RECENT PUBLICATIONS

*The Journal of the Iron and Steel Institute, No. 1, 1903;* 814 pages, edited by Bennett H. Brough. E. & F. N. Spon, London. — This volume includes the minutes of proceedings of the May, 1903, meeting of the Institute and the usual excellent " Notes on the Progress of the Home and Foreign Iron and Steel Industries." The following papers were read at the meeting and are published with discussion :

*Presidential Address,* Andrew Carnegie.

*On the Development of the Continuous Open-Hearth Process,* by B. Talbot, with 20 pages of discussion, the participants to the discussion being Edwin Martin (Pittsburg), Percy Gilchrist, Edward Riley, E. H. Saniter, F. W. Paul, George Ainsworth, R. M. Daelen (Düsseldorf), Professor Turner, F. W. Harbord, T. H. Colley, and H. H. Campbell.

*Hollow-Pressed Axles,* by Camille Mercader, discussed by James Kitson, R. M. Daelen, H. Bauerman, Vaughan Hughes, Samuel Lloyd, E. Windsor Richards, J. Hardisty, and S. A. Houghton.

*The Influence of Sulphur and Manganese on Steel,* by J. O. Arnold and G. B. Waterhouse, with 16 pages of discussions by J. E. Stead, F. W. Harbord, Vaughan Hughes, S. A. Houghton, McWilliam, and Bertram Blount.

*The Application of the Electric Furnace in Metallurgy,* by Albert Keller, discussed by A. H. Allen, J. O. Arnold, B. H. Thwaite, Greiner, J. E. Stead, E. K. Scott, G. Ritchie, and Professor Turner.

*Portland Cement, Manufactured from Blast-Furnace Slag,* by the Chevalier C. de Schwarz, discussed by T. C. Hutchinson, J. E. Stead, Bertram Blount, B. H. Thwaite, and Professor Turner.

*A New Blast-Furnace Top,* by Axel Sahlin, discussed by H. Pilkington, Greiner, W. J. Foster, and Horace Allen.

*The Thermal Efficiency of Hot Blast Stoves,* by B. H. Thwaite, discussed by Tom Westgarth, H. Bauerman, Vaughan Hughes, James Linday, and Horace Allen.

*Note on the Alleged Cementation of Iron by Carbon,* by J. E. Stead, discussed by E. F. Lange.

*The Open-Hearth Process,* by Lieutenant-Colonel Leandro Cubillo, discussed by E. H. Saniter.

*Note on the Analysis of a Specimen of Sussex Cast Iron,* by Professor Thomas Turner.

*Determination of the Points of Allatropic Changes of Iron and Its Alloys by the Measurement of the Variations in the Electric Resistance,* by O. Boudouard, Carnegie Research Scholar.

*The Heat-Treatment of Steel Under Conditions of Steelworks Practice,* by Alfred Campion, Carnegie Research Scholar; discussed by F. W. Harbord, and C. H. Ridsdale.

*The Influence of Varying Casting Temperature on the Properties of Alloys,* by Percy Longmuir, Carnegie Research Scholar.

*The Mineral Industry, Vol. XL;* 891 pages. Edited by Joseph Struthers. Published by the *Engineering and Mining Journal,* New York. Price, $5.00.— This valuable annual publication is always welcome by those interested in the metal industry. The present volume is fully as good as its predecessors. The following contributions are of special interest to iron Metallurgists: *Coal and Coke,* by Samuel Sanford, D. H. Newland and Henry Fisher; *Iron and Steel,* by Frederick Hobart; *Manufacture of Mineral Wool,* by Edwin C. Eckel; *Natural Gas Industry,* by W. H. Hammon; *Progress of Metallography in 1902,* by William Campbell; *Alloys Steels,* by Alexander Mathews; *Slag Cement and Slag Brick Manufacture During 1902,* by Edwin C. Eckel.

*Siderology — The Constitution of Iron Alloys and Slags,* by H. F. v. Jüptner; 344 pages. Illustrated. Translated from the German by Charles Salter. Published by Scott, Greenwood and Co., London, 1902. Sold by D. Van Nostrand Co., New York. Price, $5.00.— The author of this book needs no introduction to the reader of *The Iron and Steel Metallurgist;* his excellent work in dealing with some of the most difficult problems related to the constitution of carburized irons has made his reputation worldwide. The translation into English of his *Siderology* should be welcomed by all students of the metallurgy of iron and steel. It is an able review of a decade of remarkable activity and production on the part of many scientific Metallurgists, and which also

contains the results of many original investigations, as well as valuable speculations. The subject matter is divided into four sections: I. The Theory of Solutions; II. Micrography; III. Chemical Composition of the Alloys of Iron; and IV. The Chemical Composition of Slag. The typography of the book and the illustrations are excellent.

*Jahrbuch für das Eisenhüttenwesen*, (Year Book of the Iron Industry). Supplementary to *Stahl und Eisen*. An account of the progress in all departments of the iron industry during the year 1901. By Otto Vogel, Düsseldorf, 1903. Price, 10 marks.— Like the first volume published last year, this book describes concisely the most important developments that have occurred during the year 1901 in all departments of the iron and steel industry, numerous references being given. It should prove of much value to all iron Metallurgists able to read German.

*The Hardening and Tempering of Steel,* by F. Reiser. Translated from the German by Arthur Morris and Herbert Robson. 120 pages. Published by Scott, Greenwood & Co., London, 1903. Sold by D. Van Nostrand Co., New York. Price, $2.50.— The book is divided into the following chapters: I. Steel, Description and Classifications; II. Chemical and Physical Properties of Steel, and Their Causal Connection; III. Classifications of Steel, According to Use; IV. Testing the Quality of Steel; V. Steel Hardening; VI. Investigation of the Causes of Failure in Hardening; VII. Regeneration of Steel Spoilt in the Furnace; VIII. Welding Steel.

In the opening paragraph a statement is made which is not likely to be endorsed by many steel Metallurgists. "If the carbon is less than 0.45 per cent," the author writes, " the hardening becomes barely noticeable, and the iron is no longer steel but wrought iron." The book contains other statements to which exceptions might be taken. Several typographical errors occur, such as the repeated writing of Professor Ledebur's name, Le Debur. The treatment of the subject, nevertheless, is in many respects very good and the book should commend itself to those interested in the hardening of steel.

*The Elasticity and Resistance of the Materials of Engineering*, by W. H. Burr; 1100 pages, 8vo. Illustrated. John Wiley & Sons, New York. Price, $7.50.— This is the sixth edition of Professor Burr's well-known book, which is now enlarged from 770 to 1,100 pages. In the publishers' note it is stated that the general arrangement has been considerably changed to make it better adapted to the practical operations of the engineer's office and, at the same time, become even more useful to the engineering student. Since steel has completely displaced wrought iron for structural purposes, this metal as used under all conditions for structures or machines is given extended consideration, including the effects of chemical constitution and shop manipulation. The physical properties of the new steels, such as nickel and manganese steels, are fully given. The same observation applies to aluminium, copper, tin, zinc, and their alloys. There is a remarkably full presentation of all the physical properties, both elastic and ultimate, of the modern Portland-cement mortars and concretes, including beams of those materials. The latest investigations regarding the elastic and ultimate resistances of stone and masonry columns and beams are completely set forth. Probably one of the most important sections of the book is that relating to concrete-steel members. This " armored " combination is now being largely used by the most progressive engineers. The treatment of this important class of beams or other members is for the first time in the English language systematically and completely given in this book. The practical applications of the theory of concrete-steel construction are illustrated by the operations of actual design, in which the values of such empirical quantities as the coëfficient of elasticity and ultimate resistance are fully shown.

*La Chimie Physique et Ses Applications.* (Physical Chemistry and Its Applications), by J. H. Van'T Hoff. Translated from the German by H. Cowing. A. Hermann, Paris, 1903. 80 pages, illustrated. Price, francs, 3.50. — Professor Van'T Hoff in June, 1901, delivered eight lectures on physical chemistry and its applications which are here published in book form. The third and fourth lectures, which deal with the industrial applications of physical chemistry, will be found of special interest to the Metallurgist, since they refer to the application of the laws of solution to the construction and properties of iron and steel.

# PATENTS

## Relating to the Metallurgy of Iron and Steel

### UNITED STATES

741,618. ART OF MAKING METAL CASTINGS.—William A. Bole, Pittsburg, Pa., assignor to the Westinghouse Machine Company. An improvement in making metal castings in sand molds, which consists in promoting approximately synchronous shrinkage of all portions of the metal by subjecting the sand which constitutes the mold, adjacent to different portions of the casting, to the cooling action of independently-regulated quantities of cooling fluid.*

741,680. HOT-BLAST STOVE.— Herbert Lang, Oakland, Cal. In a hot-blast stove or air-heating apparatus, a series of more than two adjacently-placed air-cells in communication alternately at top and bottom, an air-inlet to the first cell, an air-outlet from the last cell, a series of super-imposed retort-sections forming a continuous tier in each cell all in communication at bottom, a heating furnace, and means for sending the products of combustion of said furnace into and out of all the said retorts in succession, in reverse direction to that of the air current through said cells.*
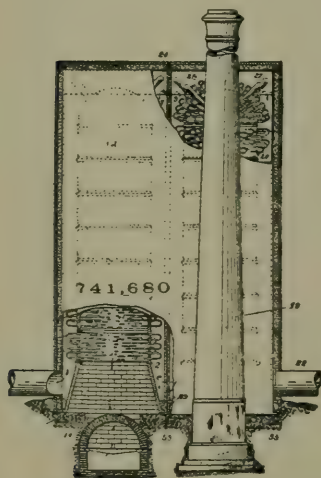
741,702. ROLLING MILL.— John W. Offutt, Ellwood City, Pa., assignor, by mesne assignments, to National Tube Company. In a rolling mill, the combination of two sets of rolls rotating in opposite directions, a mandrel bar and mandrel, and means for operating the same, and means for opening one set of rolls and simultaneously closing the other set.*

741,727. HIGH-TEMPERATURE FURNACE. — John T. Shadforth, Walker-on-Tyne, England. A furnace for producing a high-temperature reducing-flame, comprising a liquid-fuel-vaporizing chamber, a combustion chamber, water vessels arranged one on each side of the vaporizing and combustion chambers, as described, connections between said vessels and the combustion chamber, a main flue and a branch flue opening communication between the main flue and the combustion chamber.*

741,751. CASTING METALS. — Alfred M. Acklin, Pittsburg, Pa., assignor to Heyl and Patterson, Pittsburg, Pa. A method of casting pig metal, consisting in pouring the metal into traveling molds, partially submerging said molds but not the metal therein in water, and at the same time keeping the metal from contact with the water while in the molds and discharging the metal from the molds into the water and completely submerging the metal therein.*

741,752. APPARATUS FOR CASTING METALS. — Alfred M. Acklin, Pittsburg, Pa., assignor to Heyl and Patterson, Pittsburg, Pa. In an apparatus for casting pig metal, the combination with a suitable frame, of wheels mounted thereon a longitudinal endless carrier passing around said wheels, rollers on said carrier, a water-trough, tracks located within and parallel to the sides of said trough upon which said rollers travel, a tank at the rear end of said carrier into which the pigs are discharged by the carrier, and a car within said tank adapted to catch the pigs as they are discharged by the carrier and to carry them from the tank.*

742,018. REDUCING-FURNACE. — William W. Fyfe, London, England. In means for converting metallic oxides into metal, the combination of a smelting-hearth, a melting-pot, a connection between said hearth and said pot, and flues whereby the flame and products of combustion are led over the smelting-hearth and then under the same and then under said pot, the melted metal in said pot and said connection being kept out of direct contact with the flame and products of combustion.*

742,037. COKE-DRAWER. — William Kearns, Mammoth, Pa. A device comprising, in combination, a frame or casing designed to be extended into a coke-oven, means for gradually advancing the same, an endless conveyer, an incline extending from the end of the frame, a clawer for forcing the coke up such incline, and means for actuating such clawer.*

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*Engineering and Mining Journal.*

742,223.  Hot Saw.—Peter C. Patterson, McKeesport, Pa., assignor to National Tube Company, Pittsburg, Pa.  In a metal-saw, the combination with a support for the article, a swinging frame, a rotary saw mounted therein in position to swing across the support, a driving pulley for the saw arbor, a belt, and a power-driven pulley mounted on a center separate from that about which the saw frame swings and so located that the distance between its center and the center of the saw pulley increases as the saw swings to its final active position.*

742,314.  Ingot-manipulating Mechanism for Rolling-mills. — John A. Hampton, Handsworth, and James Roberts, West Bromwich, England.  In mechanism for turning over and otherwise moving ingots, blooms, billets, and the like, in connection with rolling-mills, the combination of two movable heads, a tilting shoe connected to one of such heads by a pivotal connection permitting an independent bodily movement of said shoe relative to such head, and suitable means, in operation, for causing said shoe to tilt.*

742,316.  Electrometallurgy of Iron and Steel. — Henri Harmet, St. Etienne, France.  The continuous conversion of iron ores directly into iron and steel by three electrometallurgical steps, comprising first the fusing of the minerals in the presence of hot gases derived from the second or reducing operation aided by the application of an electric current to the materials to be fused, then reducing under the combined action of an incandescent reducing-carbon and of the application of an electric current by the passage of the fused and reduced materials through a column of said reducing-carbon, and finally refining the mass by the application of an electric current thereto.*

742,367.  Rolling-mill. — Maximilian M. Suppes, Elyria, Ohio.  In a rolling-mill, the combination with the pinions, the rolls, and the couplings which connect the rolls and pinions, said rolls having necks or gudgeons of unequal lengths at their two ends, and reversed end for end, whereby the longer necks or gudgeons of the adjacent ends project in opposite directions and thereby bring said couplings into staggered or alternating relation to each other.*

742,368.  Roll-adjusting Mechanism for Rolling-mills. —Maximilian M. Suppes, Elyria, Ohio.  In a rolling-mill, the

combination with a housing in which the movable rolls are journaled, of a housing-nut seated therein and formed with a broad horizontal shoulder terminating in an upper portion or neck and having an upward bearing in said housing, said nut having an interior thread which terminates at a point below the said shoulder.*

742,519. SMELTING FURNACE FOR THE CONTINUOUS PRODUCTION OF STEEL. — Stanislaus Surzycki, Czenstochowa, Russia. A smelting furnace provided with a plurality of tap-holes at different levels and in different vertical planes, and a single discharging-trough provided with branches extending to each tap-hole.*

742,645. ROLLING-MILL. — Otto Heer, Düsseldorf, Germany. A rolling plant for the gradual rolling and shaping of tubes and other hollow bodies comprising a roller-frame *a,* shouldered rollers therein capable of gripping the work in one movement and releasing the same upon the other movement during their oscillation, a pendulum-like part *c* carrying the roller-frame at its lower end, an elevated shaft *d* upon which the pendulum-like part *c* oscillates, means for supporting the elevated shaft, a horizontal spindle *k* adapted to carry the piece to be worked and means for moving forward the said spindle and for giving it a rotary movement when the roller frame on its return oscillation moves toward the said spindle.*

742,441. APPARATUS FOR THE MANUFACTURE OF STEEL. — Henry Johnson, Brunswick, Victoria, Australia, assignor of one-half to George William Frier, Glenferre, Victoria, Australia. An apparatus for the manufacture of steel, consisting of an integral structure and comprising a converter, a melting furnace having a covered passage connecting it directly to said converter for supplying molten metal thereto, and a feed-metal-heating furnace also having a covered passage connecting it directly with said converter.*

742,987. WIRE-DRAWING MACHINE. — James A. Horton, Providence, R. I., assignor to Iroquois Machine Company, New York, N. Y. In a wire-drawing machine, a die, a drum, a wire-forwarding means adapted to slip circumferentially on said drum and frictionally driven at the speed required by the call or tension of the wire, and means whereby the friction surfaces of the drum and the wire-forwarding means may be uniformly and continuously lubricated.*

742,919. Peep-hole Attachment for Blast Furnaces.—
Adam L. Smith, Pittsburg, Pa. An attachment comprising a plate,
a detachable seat carried thereby, a hinged member carrying an
eyesight provided with a head, and means for forcing the head
against the seat.*

743,715. Manufacture of Steel. — Robert A. Hadfield,
Sheffield, England. In steel-making by the pneumatic method,
the process of controlling the oxidation of the molten metal during
the conversion thereof into steel, which consists in making suc-
cessive introductions of manganese to the charge subsequent to the
commencement and before the completion of the blow.*

744,014. Method of Cutting Steel Plates. — Edwin W.
Lewis and John S. Unger, Munhall, Pa. A method of finishing
armor-plate consisting in carburizing the face thereof, liquid-
quenching the carburized portion, and then cold-sawing through
the plate by a rapidly-revolving metal disk.*

744,031. Process of Manufacturing Steel. — William B.
Brookfield, Syracuse, N. Y. A process of producing steel, consist-
ing in fusing iron, chromium and molybdenum in bulk together,
reducing the resultant product to a subdivided or fragmentary
condition, and then fusing said reduced product in crucibles.

744,208. Composition for Hardening Steel. — Gottlieb
Kolb, Mannheim, Germany. A composition of matter for harden-
ing steel and rendering it tougher, consisting of substantially 700
grams of colophony, 100 grams of copper vitriol, 300 grams of
prussiate of potash and 100 grams of linseed-oil.*

744,319. Support for Cooling Plates or Coils in Blast-
furnaces. — Austin Farrell, Gladstone, Mich., assignor of one-
half to William G. Mather, Cleveland, Ohio. A blast-furnace
having a metal frame encircling its bosh-wall and provided with
a series of cooling plates or coils extending inwardly from said
frame, and means for securing the outer portion of said cooling
plates or coils to said frame in a manner permitting said plates or
coils to be removed without disturbing said frame.*

744,535. Rolling-mill. — Charles M. Grey, New York,
N. Y., assignor to American Universal Mill Company, New York,
N. Y. In a rolling-mill, a longitudinally or endwise shiftable
upright reducing-roll adjusting laterally toward and from the path
of the blank or work and arranged to operate upon one portion of

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the blank or work; another reducing-roll arranged in a horizontal plane and in position to operate upon another portion of the blank or work and adjustable toward and from the aforesaid path; a vertically-adjustable support for the upright roll; means instrumental in laterally adjusting the upright roll toward and from the path of the blank or work; means instrumental in shifting the aforesaid roll-support vertically, and means whereby the said roll support-shifting means is operated to shift the said roll-support when and in the same direction in which the horizontally-arranged roll is shifted during a readjustment of the horizontally-arranged roll, and the aforesaid roll-support-shifting means and the means instrumental in laterally adjusting the upright roll relative to the path of the blank or work being capable of being operated independently of each other.*

## GREAT BRITAIN

26,065 of 1902. MAKING MAGNESITE BRICKS. — H. G. Turner, London. Heating magnesia until it melts and allowing to crystallize, then grinding and making into bricks for metallurgical furnaces by mixing with magnesium chloride or water glass.*

22,282 of 1902. CLEANING BLAST-FURNACE GASES. — C. H. Fowler and E. A. Medley, Huyton, Lancashire. Improved spraying apparatus for cleaning blast-furnace and coke-oven gases from solids and tar for use in gas engines.*

14,305 of 1903. BLAST HEATER FOR CUPÓLAS. — Albert Seydel, Fretigny, France. Method of utilizing the waste heat of cupola furnaces for heating the blast for the tuyères.*

## GERMANY

Kl. 31c. No. 141,091, 30 May, 1900. DEVICE FOR MIXING BLAST-FURNACE IRON DIRECT FROM THE FURNACE WITH IRON MELTED IN THE CUPOLA IN A HEATED MIXER, AND FOR POURING THE MIXTURE. — Hugo Buderus in Hirzenhain, in Oberhessen. First a corresponding amount of fluid slag (blast-furnace slag) is charged into the furnace, either directly from the blast furnace or by means of the familiar transportable casting ladles. By this means the furnace is warmed beforehand to a very great degree without employing any especial fuel. Then a gaseous, or fluid, or

solid fuel is applied over the glowing layer of slag, which is kindled by the hot slag. Thus in a very short time a high temperature which reaches that of white-hot iron is obtained.

In this mixer, brought to this high temperature, the iron is poured either from the blast furnace, or from the cupola furnace, as one pleases. The mixed iron is kept by means of the firing at the temperature necessary for the casting; on the other hand, moreover, the layer of slag previously formed preserves the metal from any injurious influence due to firing.*

Kl. 49f Nr. 140,801, 11 März 1902. MACHINE FOR THE MANUFACTURE OF A PLATE WITHOUT DIMINISHING THE WEB OF THE RAIL.—Dr. Ing. Jacob Lukaszozy in Königshütte (Oberschl.). The pressing stamp *b* has, in addition to its movement against the matrix *m*, a movement in two opposite directions, as shown by the two arrows. This second motion is accomplished after the completion of the first. Therefore the sharp edges of the stamp *b* together with the sharp edges of the matrix *m* serve as a razor for cutting off the head of the rail *k* and of the foot of the rail *f* which projects from the matrix.*

Kl. 10a. Nr. 140,725, November 6, 1901. HORIZONTAL (REVERBERATORY) COKE FURNACE WITH PERPENDICULAR HEATING FLUES. — Franz Brüggeman in Styrum (Ruhr).
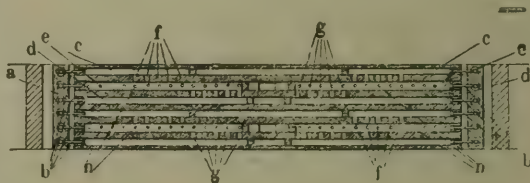
The heating gas is introduced from the gas pressure conductors *a,* lying in front of each side of the furnace, through blast tubes, *b,* directly into three canals *c, d,* and *e,* which lie below the level of the furnace bed. The gas introduced into the canal *c* goes through the opening *f,* and that entering into the canal *d* through the opening *g* into the canal *e.* It distributes the whole amount of

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* *Stahl und Eisen.*

gas equally over the whole length of the canal *e* in which it burns after having become mixed with the air which enters through the little openings at the bottom, *n*. The gases of combustion are then spread equally through the perpendicular heating flues.*
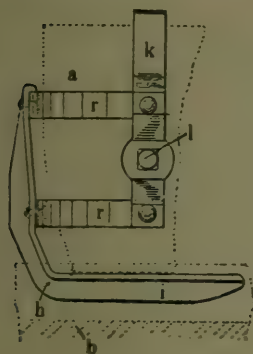


Kl. 31a. Nr. 139,128, September 18, 1901. DEVICE FOR REMOVING THE CRUCIBLE FROM THE SMELTING FURNACE, AND TIPPING THE SAME. — David Laird, in Forfar (Schott.). The device consists of a bent foot *h*, with horizontal arm *i*, which carries the crucible *a*, and is depressed to a corresponding depth on the furnace floor. On the bent foot *h*, are fastened round pieces *r*, which support the handle *l* upon the brace *k* and serve to hold the crucible on the side.*

Kl. 8a. Nr. 139,096, January 24, 1902. DEVICE FOR RAISING AND LOWERING THE FURNACE BELL. — Benrather Maschinenfabrik Aktiengesellschaft in Benrath, b. Düsseldorf. The bell *a* is hung upon a two-armed lever *b* so that the empty bell is raised and pressed against the hopper *c*; except when the charge is upon it, when it is overweighted. In order not to let the loaded bell sink always to the lowest position by its descent with the charge, but to be able to stop it at any desired point between, the movement of the bell (upward and downward) is regulated by a



double-acting brake-piston, *d*, which is fixed in a divided double-acting cylinder, *e, f*. Since both cylinders are joined together by a system of tubes, they in themselves are an independent machine which is independently worked from a central point. Thus the valve *g*, serves to regulate the lost motion between the upper and under cylinder.*

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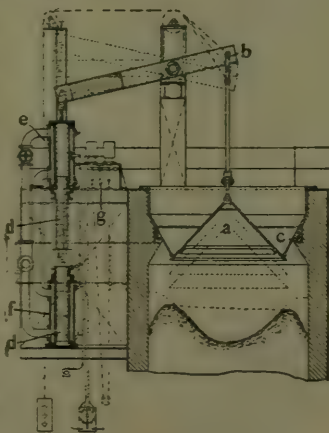
* *Stahl und Eisen.*

Kl. 12e. Nr. 140,273, June 25, 1901.  WASHING APPARATUS IN WHICH THE DUST IS DRIVEN DOWN INTO THE WATER BY MEANS OF REVOLVING CONVEYER. — *Charles* Humphrey in Hartford (England). The apparatus has revolving conveyers *i*, which occupy the entire width of the apparatus. They are placed in pairs, so that they turn in opposite directions, and in such a way that the fluid is driven into the receiving space through the water thrown from the other conveyer.*
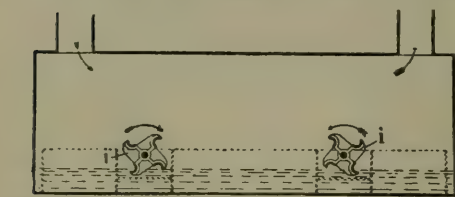
Kl. 49g. Nr. 142,754, May 28, 1902. DEVICE FOR THE MANUFACTURE OF RAILWAY SLEEPERS. — Paul Cazes in Boucan, (England). The sleepers differ from others in this, that they are reinforced by a thickening of the material at the part weakened by the stamping. Accordingly the rail supports are first stamped out and then united with a specially made reinforcing shoe by welding or pressing together. Finally the whole is pressed into the mold which corresponds to the cross section of the rail.*
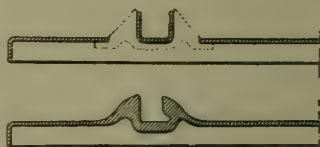
Kl. 7a. Nr. 141,107, April 10, 1902. DEVICE FOR THE ROLLING OF SEAMLESS TUBES AND THE LIKE BY THE USE OF OSCILLATING GROOVED ROLLS. — Otto Briede in Benrath, b. Düsseldorf. The device consists in this, that in consequence of the employment of a caliber which is narrowed from a very wide cross section in both directions, the working down of the piece of work by the motion of the rollers takes place in two directions while the drawing and turning of the piece of work occurs in the middle of the rollers. In this device the caliber in the roller narrows toward both sides equally, so that on one side *a* is the preparing roller, and on the other side *b*, the finishing roller.*

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* *Stahl und Eisen.*

ROBERT ABBOTT HADFIELD

## THE BRITTLENESS OF STEEL*

### By H. LE CHATELIER
#### Professor of Chemistry, Collège de France, Paris

OUR definition of the brittleness of iron and steel is relatively recent. It was for the first time expressed in a precise manner and experimentally studied by Mr. Considère, chief engineer, and by Mr. André Le Chatelier, engineer of Naval Constructions, some 15 years ago. It has always been known that certain metals such as bismuth and antimony are normally brittle, that is to say, they always break without undergoing hardly any elongation, and their fracture, therefore, requires a very small expenditure of work. On the other hand such metals as pure copper break only after having undergone a very great permanent distortion, and their rupture, therefore, requires the expenditure of much work. It had not been noticed, however, that the same metal may sometimes, according to the conditions prevailing in testing it, break with or without permanent distortion, that is to say it may or not behave like a brittle metal. Irons and steels frequently possess this intermittent brittleness. This fact remained unnoticed for a long time and no special tests were suggested to ascertain the presence of this defect before the use of the metals.

In the case of metals which are always either normally brittle

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*Received November 12, 1903.

or normally malleable it suffices in order to classify them, to measure the elongation resulting from a tensile test. It was wrongly thought that this same test was sufficient in the case of iron and steel and this led to serious errors. Too often metals whose fractures resulted in accidents had nevertheless shown much ductility when subjected to the tensile test. In order to explain these accidents, local defects or the presence of imperfections were suggested, but in most cases no traces of these could be found. At other times it was supposed that the constant use of the metals resulted in some alteration of its condition under the action for instance of repeated vibrations, but the results of tensile tests of samples of the metal cut from the vicinity of the fracture have always shown that this hypothesis was not correct.

The explanation of these accidents must be looked for in the intermittent brittleness of the metal, a brittleness which was not made apparent in the tensile test but which is felt under certain conditions, especially when the metal is in use. At all times engineers have sought, unconsciously, it is true, to guard themselves against this brittleness. This is why the specifications are constantly becoming more exacting and complicated. A study of these specifications will show that all the requirements concerning the chemical composition, the methods of manufacture, the drop test, etc., have in view to prevent this brittleness, but they fail to be effective. The brittleness of steels, that is to say their fracture without notable distortion depends upon two absolutely different causes, (1) *the nature of the metal,* that is to say, its chemical composition, its structure, the presence of foreign substances, such as slag, blow holes, etc., and (2) *the conditions, so to speak external,* prevailing while the metal is subjected to the mechanical stress which must cause its rupture ; such for instance as, the suddenness of the application of the stress, the external shape of the pieces of metal, having retreating angles or being nicked or punched, the temperature, etc. If it were possible to express in figures the quality of the metal, the external conditions of the magnitude of the brittleness itself, the latter would be represented by a surface of which the quality of the metal and the conditions prevailing during the experiment would be the two abscissas. In other words the brittleness of the metal would be the function of two independent factors, one of which at least is entirely foreign to the nature of the metal.

In reality the quality of the metal and the external conditions are the complex functions of a great many elementary and distinct factors. It can only be ascertained that various conditions under which the brittleness of steel manifests itself are the greater and therefore are met the more readily as the metal itself fulfils a greater number of the conditions having a tendency to develop brittleness. In this way extreme cases are detected, from good charcoal iron which cannot assume a brittle condition to white iron or quenched high carbon steel which break without distortion.

It is very important to define as precisely as possible the many conditions relating to the nature of the metal and to the external conditions upon which depend the brittleness.

### Nature of the Metal

I. *Chemical Composition.* — It has been known for a long time that the impurities contained in iron, and especially some of them, have a tendency to promote this brittleness, and it is often thought that these are the only important conditions to be considered. A few hundreds of one per cent of sulphur or of phosphorus are enough to render steel very brittle. This influence, however, does not always act in the same way and the effect of these impurities depends on certain foreign influences. Phosphorus for instance is especially objectionable at a low temperature; while sulphur is on the other hand detrimental at a high temperature. The action of these impurities is also modified by the presence of other substances. The objectionable influence of sulphur is to a great extent counteracted by the presence of a certain proportion of manganese. On the contrary carbon intensifies the effect of phosphorus. Finally some elements are present in steels the influence of which is only imperfectly known, as for instance hydrogen and oxygen; unknown because of a lack of satisfactory analytical methods to determine these elements.

II. *Chemical Constitution.* — The chemical constitution of an alloy is not known by the percentage of elements which it contains, because these may be present in different states of combination or simply in distant allotropic forms. Quenched steel is much more brittle than the same steel annealed. The former consists of a solid solution of carbon in iron apparently homogeneous, while the same steel annealed is made up of particles of cementite in the

middle of a mass of soft iron.   Again white cast iron which consists chiefly of cementite is very brittle, while the same metal becomes malleable through a reheating, resulting in isolating graphite from its combination.   Solid solutions of iron and of carbon moreover exist at least under three different allotropic conditions, (1) austenite, a substance which is not very brittle, constituting the greatest portion of nickel-steel and containing a large percentage of nickel as for instance ferro-nickel, an alloy possessing remarkable ductility, (2) martensite, the second constituent of ordinary quenched steels, which is very freely brittle, and (3) trostite and sorbite, elements which are ductile or slightly brittle, and which impart some special properties to steels which have been subjected to a mild hardening or which have been tempered. These facts are too well known to require here more than a mere mention.

III.   *Structure of the Metal.* — The influence of the structure of the metal is of as great importance as its chemical composition and constitution.   Metals of identical composition may have very different structures; that is, the distribution of their components may be very dissimilar and on that account vary much as to their brittleness.

The structure of steel depends essentially upon three factors:

*Casting  Temperature.* — Mr.  Longmuir  showed  that  steel which is cast at a temperature too high or too low exhibits a tenacity and a ductility considerably smaller than those of the same metal cast at the proper temperature.   Subsequent treatment of the metal may decrease this influence of the casting temperature, but it cannot remove it completely; the steel will always remain more brittle.

*Hot Work.* — Hot work and especially forging and rolling decreases considerably the brittleness.   Cast steels are always more brittle than forged steels, and it was even thought for a long time that mechanical work was the only means of reducing the initial brittleness of the cast metal.

*Heat Treatment.* — Heat treatment is as effective as mechanical treatment in removing brittleness and frequently offers an easier means.   These treatments are becoming more and more important in the industrial handling of steel.   It had been known for a long time that a prolonged reheating of iron and steel at a high temperature frequently resulted in great brittleness.   It was then said that the metal was burned, an expression which in most cases

is not correct; because this brittleness may appear without any change in the chemical composition and may result from a simple change of structure, the grains of the metal having become larger. Colonel Caron showed 40 years ago that it was possible to restore the metal by a new heating under suitable conditions so that heat alone may undo the objectional results it had produced. Subsequent experiments by Brinnell, Tschernoff, Osmond, Howe, Stead, and Sauveur have ascertained more precisely the conditions of this thermal treatment, and have demonstrated its value in improving the quality of metals after forging. Annealing or hardening or double-hardening, that is to say, the succession of two hardenings performed respectively at a temperature higher and lower than the transformation point of the metal, are more and more used in steel works. The essential condition of this treatment which is to confer a fine grain to the metal, consists in heating it a little above its transformation point and then in cooling it, the results being the better, the more quickly these operations are conducted. The minimum temperature of the reheating operation necessarily depends upon the transformation points of the metal. It varies from 950° in the case of very mild steel to 800° for high carbon steel.

IV. *Cold Working.* — Cold working also imparts brittleness to steel; but the reasons for this are imperfectly understood. A metal distorted by a mechanical stress changes first its external form; but at the same time its other properties also undergo certain modifications similar to those which result from chemical transformations, but of much less importance. The density and the mechanical properties for instance are modified; the elastic limit is increased in regard to stresses which have a tendency to continue the distortion in the same direction, and, on the contrary, is decreased in regard to stresses of opposite direction. Cold working also influences brittleness, although in a varying manner. Some very pure metals having been subjected to treatment, which confer upon them a minimum of brittleness, may be subjected to very great permanent distortions without any reappearance of brittleness. In other cases, on the contrary, brittleness appears after very slight distortions. Mr. Considère, for instance, has called attention to the fact that steel containing much phosphorus becomes extremely brittle through cold working, and even after a hammering so slight as not to produce any apparent distortion; plates made of

such steel fail upon being punched.  André Le Chatelier has shown that the distortion of metals of good quality may be harmless if performed in the cold, but becomes very dangerous if effected between 100 and 400° C.  Very slight elongations produced under these conditions, may cause a reduction of over 50 per cent in the ductility of a metal whose original elongation was 30 per cent. This fact is often disregarded in working steel.

## External Conditions

The conditions prevailing when the metal is subjected to a stress, have an influence at least as great as that of the nature of the metal, upon the result of the stress; and this is the reason why the metal, according to these conditions, will or will not be brittle. It occurs very frequently that a metal will not reveal any brittleness when subjected to the ordinary tensile test, while it will break when in use under the action of a very slight impact.  The most important conditions, of which the influences have been so far studied from this point of view, are as follows:

• I.  *Impact.* — It is well known that a sudden shock will produce fracture more readily than a slowly applied stress.  This is because the maximum strain, produced during an impact, increases very rapidly as long as the distortion of the metal remains slight, which is the case during the period of elasticity.  By means of a shock, strains are readily developed greatly superior to the elastic limit of the metal, while such are not readily produced by a slowly applied stress; but it does not follow from this, however, as it might at first be inferred, that the work required to produce rupture is less in the case of an impact.

Messrs. Considère and André Le Chatelier have shown, however, through a series of impact tests with wires, that the work required to produce rupture decreases rapidly, and finally becomes nearly nil, as the height of the fall, and therefore the speed of the shock, increases.  The elastic limit increases, approaching more and more the tensile strength which, on the contrary, remains quite constant.  When these two factors have become identical, rupture takes place without any permanent distortion; that is to say, through an expenditure of work very slight compared to that of the ordinary tensile test.

Subsequent experiments of Messrs. Frémont and Charpy, con-

sisting in breaking by impact, bars of steel supported at each end, have, on the contrary, led to the conclusion that the work necessary to cause rupture by slowly applied stress and that required in the case of an impact, are nearly equal. In a few instances some metals required an amount of work smaller in the case of an impact test; but these were exceptions, while in the experiments of Messrs. Considère and Le Chatelier this was the rule. It is to be noted, however, that in the case of the rupture of the wires it is their elongation which is considered, while in the transverse tests of the bars it is especially their reduction of area.

. Finally, Mr. De Freminville discovered this peculiarity,— that certain special steels, after having been subjected to a certain heat treatment, required to be broken by impact transversally, an amount of work much greater than that required in the ordinary tensile tests.

II. *Temperature.*— Daily experiments show that iron and steel are much more brittle at low temperatures, and it is customary in winter to throw warm water on the chains of hoisting appliances in order to prevent their breaking when they have to lift heavy weights. The tensile test, however, requires an amount of work which is greater at a low temperature than at higher temperatures. André Le Chatelier has shown that the lower the temperature the smaller is the velocity required to cause the metal to exhibit brittleness under the tension test. In some cases, below 0° C., a loading speed of one minute is sufficient to produce rupture without elongation; but this result varies much with the quality of the metal and especially with the thermal treatment to which it has been subjected. Steels which have undergone the double hardening treatment are but slightly affected by the fall of temperature.

On the contrary when metals are heated above the atmospheric temperature to the vicinity of 100° or still better to 300° — in other words when the metal is heated until it has acquired a blue color, the brittleness may completely disappear even in the case of soft steels which at the ordinary temperature were as brittle as glass.

At these temperatures in the case of a tensile stress slowly applied, the elongation decreases greatly, although it remains quite considerable. This elongation can no longer be entirely destroyed by an impact test. A very soft steel, for instance, which, because of a defective thermal treatment, had assumed a coarse crystalline structure and which could be broken by a blow at the ordinary tem-

perature, did not exhibit any brittleness even after having been nicked, when it was heated above 100°. This fact is well known in shops where plates which must be distorted are frequently heated, by means of shavings, to a temperature not exceeding the blue color, in this way avoiding the breaking of the sheet. This proceeding offers the very great objection that it alters greatly the quality of the metal, making it very brittle when it is again cooled to ordinary temperature, the user being then the only one, however, to suffer from it. If it were positively known that a metal was not brittle in the cold, it could be without any risk distorted without being reheated, which distortion would not then affect its quality like that performed at a higher temperature.

III. *Shape of the Metallic Pieces.* — The angular parts of a metallic piece are like so many points of weakness which have a tendency to break with very little if any distortion, and are, therefore, a cause of brittleness. This very fact was used to devise a test for brittleness by nicking a bar which is then subjected to a drop test having a tendency to open this cut. In this manner fracture takes place without distortion, the more readily, the sharper the cut. With a cut having at the bottom a width of a few hundredths of a millimeter only, metals break without distortion, except those of very first quality such as very mild steel having been subjected to double quenching, and certain nickel steels. These only exhibit some distortion before breaking, and, therefore, are not brittle. With such a narrow cut brittleness is exhibited by half of the extra mild steels manufactured. In almost every case, however, with these soft steels, brittleness disappears completely when they are subjected to a suitable thermal treatment. With an infinitely large cut, that is to say, without any cut at all, no soft metals manufactured today exhibit any appreciable brittleness. It is seen therefore, that the number of metals exhibiting brittleness will vary very much according to the width of the nick. In the present condition of manufacture it is possible to require, without any increase of cost, metals which do not exhibit brittleness with a cut of a few millimeters wide, and it may be hoped that, through the incessant progress of metallurgy, it will be possible eventually to demand an absence of brittleness in the case of a narrower cut.

IV. *Various Conditions.* — There are undoubtedly other conditions which have a tendency to promote brittleness. In some cases the vibratory motion of a piece of metal, while it is also sub-

jected to a stress, appears to induce brittleness. Further studies of
the causes of brittleness are needed.

In the alternating bending tests like those of the classical ex-
periment of Wöhler, it is possible to produce rupture of the metal
without any apparent distortion; but this cannot be called a brittle
fracture, because under each one of these bending stresses the piece
certainly undergoes small permanent distortions, requiring for each
bending an infinitely small expenditure of work. But the sum of
thousands and millions of such stresses cannot be overlooked. The
rupture was accompanied by the expenditure of considerable work,
and cannot, therefore, be considered as brittle even if the broken
piece does not exhibit any trace of distortion.

## Tests for Brittleness

The danger of using brittle steel is too evident to insist upon
the usefulness of a test capable of detecting brittleness. In recent
years a great many investigations have been carried on in France
to devise such a test. Several methods have been studied. Mr.
Considère has proposed to compare the angle of fracture of the
metallic pieces which had been previously punched. When a metal
is brittle the fracture under these conditions takes place without
much deflection. These experiments were recently continued by
Mr. Guillery; but no conclusive results were obtained. This
method moreover is only suitable in the case of sheets and plates.

André Le Chatelier suggested the fracture by impact of test
bars previously nicked. This method has been received with much
favor. Several appliances have been devised to measure the
amount of work expended in causing rupture. Among them we
may mention those of Mr. Frémont, of Mr. Le Blanc, the pen-
dulum of Mr. Charpy, and the apparatus of Mr. Guillery. A sim-
ple method consists in measuring the angle of fracture instead of
the amount of work, as it does not require the use of any special
appliances. This angle in the case of bars having the same di-
mensions, is a function of the amount of work required to cause
rupture. From the measure of the angle the amount of work may
be calculated and vice versa.

In this test the most delicate point to adjust is the depth and
the shape of the cut. Mr. Frémont recommends small test bars,
eight millimeters thick with a nick one millimeter deep and one

millimeter wide. Mr. Charpy suggests test bars 30 millimeters square, cut to half their width by a cylindrical hole measuring six millimeters in diameter. These two extreme dimensions have serious objections, and it is probable that an agreement could be reached upon a dimension half way between. A desirable arrangement for instance is obtained in using test bars one centimeter thick nicked to one-quarter of their thickness by a cut two millimeters wide, the bars resting upon supports five millimeters apart. No theoretical or experimental reason can be given to prove the advantage of one dimension over another. It is merely an arbitrary arrangement which should be decided upon once for all. This is what was done in the case of the tensile test bar when the proportion of the length of the bar to its diameter was selected.

The usefulness of such tests is evident to all engineers who have used it; but we should not go to the extreme and infer that this brittleness test is the only one required. Absence of brittleness is certainly an essential quality; but hardness and elastic limit have also their importance, sometimes even greater, according to the uses to which the piece of metal is to be put. At any rate the determination of the elastic limit and of brittleness should be the tests receiving the most attention. It would even seem that for all the ordinary uses of steel and iron, when they are not to be subjected to additional work at a high temperature, these two tests should suffice. Tensile tests, bending tests, conditions of manufacture, of chemical composition, retain then only a secondary interest, and it is not impossible that they will eventually be omitted from the specifications.

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## ALTERNATE BENDING STRESSES*

By CHARLES B. DUDLEY

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WHAT is the present state of our knowledge as to the strains involved, and the kind of metal best calculated to resist, alternate bending stresses?

A complete discussion of this problem would require a long article, and at the present time it is not designed to attempt so much. The most that we hope to do is to state the problem, and

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possibly throw a little light upon it, with the idea in mind of opening up the subject for further study.

The effect of repeated alternate bending stresses is almost too well known to need comment. Sooner or later if the stress is high enough, all metal will rupture under alternate bending stresses. The simplest illustration is perhaps the breaking of a piece of wire in the hands. It is well known that a few times bending back and forth of a piece of wire, will break it. It is obvious from the nature of the case that the metal in the wire is subject alternately to tension and compression as the successive bendings take place. The bending in one direction subjects approximately one-half the metal to a tension strain, and the other half to a compression strain, while the bending in the reverse direction subjects the first half to a compression strain, and the second half to a tension strain. One of the best illustrations in actual service, is perhaps the car axle. It is obvious that the journal of a car axle gets alternating bending stresses, that is, the metal is subject to alternate tension and compression with each revolution, and that during the life of an axle, these stresses are many thousand, perhaps million, times repeated. Again the metal between the wheels is in like manner subject to alternate tension and compression with each revolution. We fancy those who have never devoted much thought to the subject, will be astonished at the wide prevalence of alternate bending stresses in metal sustaining stress. Every moving vehicle is full, if the expression may be used, of alternate bending stresses. In a locomotive the driving axles are subjected to these stresses, due to the load, and due to the alternate action of the steam in the cylinder. The crank pins are likewise subjected to alternate bending stresses. The piston rod where it goes into the cross head, if there is a little lost motion, due to wear between the cross head and the guides, is subjected to alternate bending stresses with frequent fracture at the point of junction. The locomotive frames due to the inequality of the track are constantly subjected to alternate bending stresses. The rails and the splices are subjected to the same by every pair of wheels that pass over them. This list may be multiplied almost indefinitely. We fancy the study of these alternate bending stresses has not been sufficiently prominent in the minds of engineers.

A marked characteristic of the fractured surface of a piece of metal which has broken from alternate bending stresses, will bear

a word or two. It is well known that the fractured surface of a piece of metal broken in the testing machine, is either granular or fibrous or both, depending something on the nature of the metal. On the other hand, metal broken by alternate bending stresses, so far as our knowledge goes, never presents a fibrous appearance in the fracture. It is usually more or less smooth, possibly due to the fractured parts rubbing against each other. It has the appearance of what may be called an old break. It commences usually where the maximum stress occurs, on the surface of the section and gradually works in from the surface, until so small an amount of the
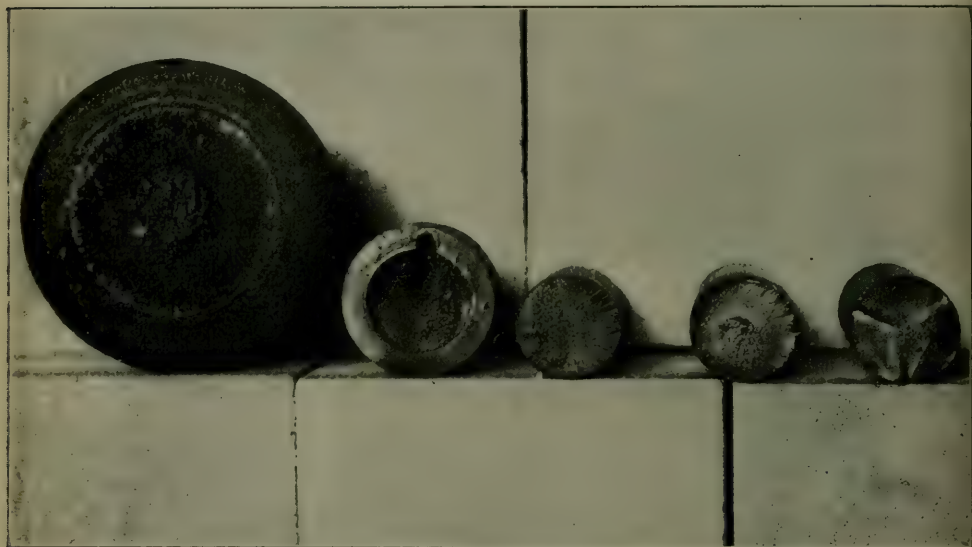


1                2                3                4                5

original area is left unbroken, that some sudden shock or stress, finishes the rupture. The part last broken usually has more or less granular or fibrous appearance. This breaking slowly, a little at a time, as above described, has led to the description of this fracture as " detail fracture," or " progressive fracture." Once seen, a case of detail or progressive fracture, will never be confounded with a rupture produced in any other way.

The accompanying cuts give good illustrations of detail fractures. No. 1 is the detail fracture of a car axle, and is a typical sample. It will be noted that the fracture started apparently all

around the circumference, and gradually worked toward the center, until only a small portion of solid metal was left, which ultimately broke under shock. No. 2 is the head of a bolt which was under vibrating stress. The fracture began at the sides as will be observed. The hole was for a pin to prevent the bolt turning round. Nos. 3, 4, and 5 are samples from a revolution-testing machine. In No. 3 the fracture began on one side, in No. 4 apparently pretty nearly at the circumference all around, and in No. 5 at apparently three different points.

Knowing the stress involved in a case of detail fracture, and the strength of the metal by actual test, we fancy no one can think on the subject, without being puzzled as to why a piece of metal, strained alternately in tension say to one-fourth or one-fifth of its ultimate strength, with a stress in compression, corresponding to each tension stress, should gradually begin to break where the maximum stress occurs, and proceed until the resulting unbroken metal is too weak to hold up the load. No doubt many engineers have asked themselves the question, why under this treatment the metal breaks, and we fancy very few have found in their studies or in their thought, any complete explanation. The reason why rupture occurs under alternate stresses, remains for further study. The fact remains, namely, that almost any piece of metal subject to alternate bending stresses, where the maximum fibre stress in one direction approximates one-half the elastic limit, will sooner or later fail by detail fracture. Indeed if Wöhler's law may be taken as a statement of fact, maximum fibre stresses of any amount will, if they are applied times enough, ultimately produce rupture. The rupture may be long delayed, and indeed if the metal is of the proper kind, and the maximum fibre stress not excessive, the part may be worn out before rupture occurs. But if the stress is high enough, or the wrong kind of metal used, the rupture may come far too soon, and whatever the stress and whatever the nature of the metal, will sooner or later appear, only provided the stress is applied times enough.

What now do we know as to the stresses, and the nature of the metal best calculated to resist them? It is to be confessed that there is great need of positive information on this subject. The only statement that we think can positively be made with our present knowledge is, that the greater the difference between the maxi-

mum fibre stress, and the ultimate tensile strength, the longer the life. In other words, contrary to what would naturally be expected, a stiff steel resists alternate bending stresses of a given fibre stress, better than a softer, tougher steel. The experience of the Pennsylvania Railroad Company on car axles on this point, may be interesting. Steel axles were first used on the Pennsylvania Railroad in 1875. The maximum calculated fibre stress between wheels was about 15,000 pounds per square inch, and the maximum fibre stress in the journal was about 6,700 pounds per square inch. The steel in these axles was an acid, open hearth steel, containing from 0.22 to 0.28 per cent carbon, and not over 0.04 per cent phosphorus, and with a tensile strength of about 65,000 pounds per square inch, and an elongation in two inches of over 25 per cent. So tough was this steel that one passenger car axle was tested under the drop with 67 blows without rupture. Some 300 of these axles were put in service, and in the course of two years, the journals began to fail from detail fracture. The matter became serious, and a consultation was held as to how to meet the difficulty. There seemed but two ways of procedure, either to increase the size, or to change the nature of the metal. Since any increase in size meant a re-design of all the parts, the latter alternative was chosen, and a metal of 80,000 pounds tensile strength was substituted for the softer steel, no other changes being made. This completely cured the difficulty, and no case of breaking in detail in car axles is known to have occurred since that time, unless the metal was of lower tensile strength than the figure given, or the axle was worn to limit, so that the maximum fibre stress was too high.

As confirmatory to this experience, and to the view that stiffness rather than toughness is the quality required to meet alternate bending stresses, the experience of some steel put into portable sugar mills for the South American trade, may not be amiss. A manufacturer of these mills which had from six to eight-inch rollers, used in those rollers a mild Bessemer steel of about 0.22 to 0.25 per cent carbon. Many of these mills were sent to South America, and in the course of a year or more, he had many complaints from the breakage of the rollers. On consultation with the makers of the steel who were familiar with the experience of the Pennsylvania Railroad above referred to, it was suggested that he try a stiffer steel. This was done, a 0.40 to 0.45 per cent carbon steel being used, and new rollers made of this steel and sent to re-

place the old ones without any change in sizes. Further breakage of the rollers was not experienced.

A third instructive incident on this point is the experience with piston rods of the steam hammer, the matter being worked out if we are right, by Mr. William Metcalf of Pittsburg. A soft tough steel was first used on these piston rods, with frequent breakages. Ultimately a very much stiffer, higher carbon steel was used, with a diminution of this trouble. It would be very interesting to have on record the details of the experiments connected with these piston rods.

It is evident from what has preceded that the three variables which are involved in this subject of alternate bending stresses, at least with our present knowledge, are the maximum fibre stress, the nature of the metal that resists this stress, and the number of applications of the stress. The most that can be drawn from our present knowledge on the subject, is that if any one is having trouble with detail fractures in any structure, the one thing to do until we know more than we do now, is to use a stiffer steel. It is to be hoped that the experiments with revolution testing machines which have been carried on more or less for the last few years, will be increased, and that sooner or later, we shall know definitely, the relation between the maximum fibre stress, ultimate strength and the number of applications of the stress, before rupture will occur. Also will not some one take hold of the problem and attempt to give a reason or explanation of the changes, which take place in the steel when subjected to repeated alternate bending stresses, which cause it to break so much below the figures shown with a stress in tension once applied?

## THE SEGREGATORY AND MIGRATORY HABIT OF SOLIDS IN ALLOYS AND IN STEEL BELOW THE CRITICAL POINTS*

### By J. E. STEAD

IN a short article published in the January, 1903, issue of *The Metallographist* by Mr. E. F. Lange, on the presence of cementite and ferrite in steel, the author has shown by his own researches and by evidence published by me, that under special con-

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-ditions the cementite and ferrite of pearlite in steel containing
·0.38 per cent of carbon separate into comparative widely separated
·masses.  Mr. Sauveur, in a postscript to this article, observes that
if pearlite is accepted as a eutectic mixture the simultaneous
occurrence of free and massive cementite in low carbon steel is
·decidedly abnormal and remains unexplained.

It is perfectly true, as Mr. Sauveur has stated, that segrega-
tion of the constituents of pearlite has not been explained, and it
·is also true that, if the condition of pearlite in forged steels, or
steels which have not been slowly cooled, is accepted as the normal
·condition, then such segregation must be considered as abnormal,
but it must be remembered that what is abnormal under one set
·of conditions may be quite normal in another.  That this is so
will presently be shown.

It was Guthrie who first used the term " eutectic," and he
applied it to what was equivalent to a solidified mother liquor in
·such alloys of metals which on melting yielded mixtures fusible
at temperatures below that of the mean of their components.  He
found that such eutectic mixtures were of constant but not of
atomic composition.

Perhaps a simple illustration taken from the domain of the
·more familiar chemical physics will convey a good idea of what
a eutectic is understood to be.  I need only refer to one of a great
·many, viz., common salt and water.

It is well known that common salt and snow, when mixed
·together, react on each other and liquefy, in other words they
·mutually dissolve each other.  The mixture is quite liquid at 0° F.,
although the melting point of salt is 780° C., and of water 32° F.
$= 0°$ C.  If the proportion of salt to water is as 1 to 1.326, and
the liquid mixture is cooled slowly down, a point will eventually
·be reached at which it will begin to freeze, and the temperature
will not then fall further till complete solidification has been
effected.  The exact temperature at which this solidification occurs
·is — 22° C.  The solid mixture of salt and water of the composi-
tion, 76.5 per cent water and 23.5 per cent salt, formerly called
·a cryohydrate, is the true eutectic of salt and water.

When this solid and frozen eutectic is treated with alcohol
·the solid water is dissolved out, leaving the salt behind unaffected,
and the microscope then shows that there are spaces which had
·previously been occupied by the ice, thus proving that the salt and

ice are quite separate from each other in very minute particles alternately arranged side by side.

If a hot saturated solution of salt and water is cooled down slowly to the eutectic freezing point, as the thermometer sinks, salt will crystallize, and continue to fall out of solution till the temperature reaches — 22° C., which is the freezing point of the eutectic mixture. This mother liquid will then freeze as a whole, separating into fine separate particles of salt and ice. On the other hand, if water is mixed with, say, 10 per cent salt, and the mixture is similarly cooled, in such a case no salt will fall out of solution, but between the temperature 0° C. and — 22° C. the water present over and above the eutectic proportion will freeze, leaving behind a more and more concentrating salt solution. Eventually, when the eutectic proportion of salt and water is reached, and heat is still drawn from it, it will solidify at the same temperature as in the case when salt was in excess.

If the two salt solutions above referred to, after cooling to below the eutectic point in a solid state, were to be examined microscopically, in the case where the salt was in excess idiomorphic crystals of that substance would be found embedded in the solid eutectic mixture. In the other case crystals of ice or solid water would be found similarly embedded.

Simple alloys such as lead and tin, antimony and lead, and many more, when their components are in eutectic proportion, exactly as in the case of salt and water, have one critical or solidifying point, and when solid neither constituent is in massive or definite crystalline form. If, however, either one or other of the constituents is in excess, it invariably is first to fall out of solution or freeze, and it is not until such excess entirely separates and the mother liquor has arrived at the eutectic proportion that the eutectic, or mother liquor, itself begins to solidify. In such a case there is an arrest in the rate of cooling at the moment when the constituent in excess begins to freeze, and this retardation is continued down to the eutectic point when a complete arrest occurs and is maintained until the eutectic is solid.

The microscope clearly shows in the solid alloys what occurs during the cooling, for the constituent which froze in advance of the liquid eutectic is invariably in comparatively large crystalline masses, sometimes in the form of idiomorphic crystals, but more generally as plates or crystallites, which are found sometimes em-

bedded in the solid eutectic, or if the specific gravity of the separated crystals is less, or greater, than that of the euetctic and the cooling is sufficiently slow, they are found respectively near the top or bottom of the cold solid alloys.*

In the case of an alloy of antimony and lead, if the antimony is in excess it is present in the form of idiomorphic crystals of antimony. If the lead is in greater excess than the eutectic proportion, it first crystallizes and is found as crystallites of the fir tree type embedded in the solid eutectic.

I shall call the eutectic mixtures which are formed when the liquid eutectic solutions become solid, primary eutectics, to distinguish them from eutectic mixtures which are formed in certain cases after the metals have become quite solid, when they cool through definite critical points. This second class I propose to call secondary eutectics.

There are many instances in which eutectics are compound in character, and contain both the primary and secondary forms together. The eutectic of iron, carbon, and phosphorus is an instance of this class.

### Segregation in Primary Eutectics

Although there is evidence that the constituents of many eutectics do segregate to a marked extent, I propose to confine my attention to one I have most thoroughly studied; viz., the iron and phosphorus eutectic.

This consists of two constituents of high melting point, which at a temperature below the melting point of either, mutually dissolve each other with a simultaneous depression of the point of solidification, and in cooling through that point breaks up into its two constituents, and, when solid, has the characteristic structure of the honeycomb type of eutectic.

The solidification of any eutectic, as well as this, may be compared with what occurs when a simple salt crystallizes from a liquid solution. When a few salt crystals, widely separated from each other, have once commenced growing in a gradually and extremely slowly concentrating liquid, they continue to develop and attract the dissolved salt, which they use for the development of their own

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* In the case of the individual constituents of the solid eutectics there is no evidence that they ever exist as idiomorphic crystals, no matter how slowly they have solidified, but they are for all that crystalline in character.

forms, and new crystals rarely form on the sides of the containing vessel. The attraction of the existing crystals tends to prevent the birth of new ones.

When on very slow cooling a eutectic begins to crystallize, its two constituents fall out of solution simultaneously at relatively microscopically wide distances apart, and continue their growth side by side till the whole of the liquid is solid. When cold the structure is very coarse, whereas, when either a hot saturated solution of salt in water or a liquid eutectic solution have the heat withdrawn from them with great rapidity, every particle of each solution as rapidly parts with a portion of its crystalline component, and instead of a few nuclei or starting points of crystalline growth, the number is excessively great, and there is a correspondingly large number of separate individual crystals.

It is possible to conceive that, were the heat to be instantaneously withdrawn, the salt would be thrown out of solution in almost molecular subdivision, or, at any rate, so finely crystalline as to require great magnification to detect the separate crystal particles, and the separate constituents of the solid eutectic would be too fine to be resolved by the highest powers of the microscope. Very slow cooling through the eutectic point of primary eutectics results in what may be called a primary but not a very pronounced segregation of their constituents.

The peculiar attractive force which crystals or crystallized particles appear to have of drawing to themselves other and smaller particles of their own kind, either from liquid or solid solution, or when the particles are in the free state, from either liquid or solid suspension, I propose to call " crystallic attraction."

### Segregation Below the Eutectic Point

I now pass on to consider what occurs after a eutectic has become solid, but is very slowly cooled through a point just below the eutectic melting point.

To explain this properly we must consider the question from two different points of view, viz.:

The first, where one or other of the eutectic constituents is in excess of the eutectic proportion.

The second, in which the whole mass is of the eutectic composition.

As an example of the first condition, I have taken the case

of an ingot of iron containing about 2 per cent of phosphorus
and a little carbon, in which there is a small quantity of the phos-
phorus eutectic distributed regularly at short distances apart
throughout the mass of phospho-ferrite.

In the moderately quickly cooled metal these isolated particles
are distinctly characteristic of the honeycombed eutectic (Photo
No. 1). Their form is irregular, and they are arranged generally
along or between the spines of the octahedral skeletons of the
ground mass, and each patch is enveloped by a fringe of pearlite.
After annealing the metal in iron ore, and very slowly cooling it
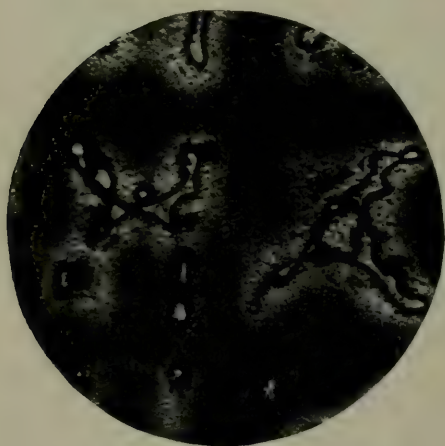


No. 1 ×80.—Metal Ingot, 2 per cent P, 0.13
per cent Carbon, before reheating.
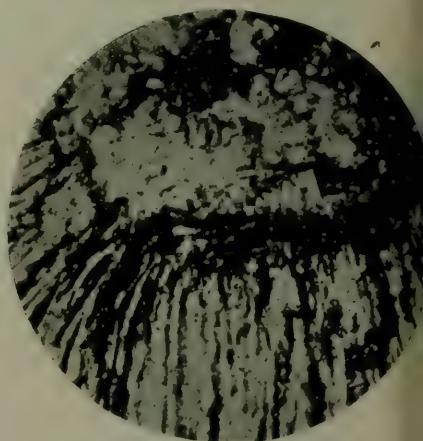
No. 2 ×5.—Phosphoretic Iron.
No. 1 "Cemented."

below the eutectic point, there no longer exists any eutectic. The
phosphide of iron and phospho-ferrite, the two constituents of the
eutectic, have completely separated from each other, and the $Fe_3P$
has changed its form and position and reformed itself into flat
plates arranged between the cleavage planes of the crystal ground
mass, and the phospho-ferrite has united with the surrounding
metal.

On again heating this metal to above the eutectic melting
point, but not to the fusing temperature of the ground mass, and
cooling in the air, the eutectic again appears, but this time in the
form of broken-up plates, rounded at their edges, and of exceed-
ingly fine duplex structure.

After completely melting the alloy, the original irregular shaped eutectic masses again appear, but this time unaccompanied with any pearlite fringe.

A portion of the original metal was then passed through the cementation process, the effect of which was to change completely the originally very coarsely crystalline structure to that of a columnar form, excepting in the exact centre into which the carbon had not penetrated. This central portion was not more than 1 c.c in volume, and was nodular in form. The photo No. 2, slightly enlarged, was taken of the metal after fracturing, so as to show



No. 3  ×80.—Micro-Photograph of     No. 4  ×250.—Pearlite Fringe.  White
Metal No. 2 at Point A.                      Fe$_3$C; Black Phospho-Ferrite.
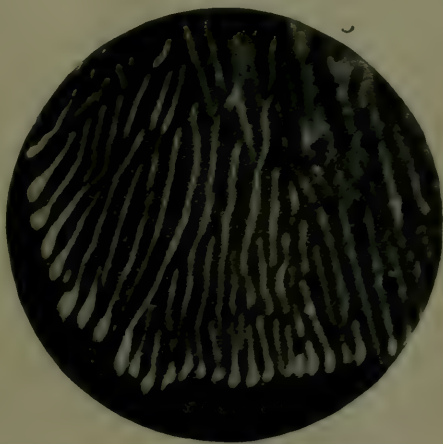
the area altered by the combined effect of the carbon and heat, and also a portion of the central portion.

No. 3 is a micro-photo of the metal at the junction of the altered and unaltered portions. It is of unique interest, for here there is pronounced evidence that not only has the central portion received no carbon during cementation, but that what little carbide there was originally present has migrated through the solid metal and joined the greater volume of carbide surrounding it. It is easy to see where the carbon is located, for the delicate tracery of bright bands radiating from patches of the phosphide eutectic below are of carbide of iron, and the fringe itself, consisting of layers of phospho-ferrite and carbide of iron, is pearlite.

The phosphide eutectic areas surrounded by pearlite are exactly of the same character as those in the original metal, with this difference, that here, owing to the exceedingly slow rate of cooling through the eutectic points, the structure of both the primary eutectic and of the pearlite is much coarser than in the original metal, which was cooled down much more rapidly.

That the central part of the nodular area contains no carbon and no phosphide eutectic, but in place has free and segregated phosphide of iron in imperfectly formed crystals, leads to the inevitable conclusion that in cooling down after the primary eutectic point has been passed, vigorous and active migration has occurred.

No. 4 photo is a micro-photograph of the pearlite fringe in No. 3, greatly magnified.

The series of knoblike extremities shown in this illustration indicate clearly enough what was actually occurring when the metal was cooling down. The rod-like lines are sections of plates of carbide of iron. In another experiment in which the metal was cooled with fair rapidity, that is to say, when the passage of the temperature through 100° below the critical point occupied about ten minutes, the bulbous terminations were absent. The inference seems obvious, that in the more slowly cooled metal, when first they fell out of solid solution, they were not there, and only became bulbous by coalescence and segregation at some temperature below the critical point. Had the favorable conditions for this movement been allowed to continue for a much longer time the terminations would have segregated to such a thickness that they would have joined together to form a solid enveloping ring of massive cementite, and possibly have eventually segregated into a large mass.

Another case may be cited, where, in addition to a considerable amount of phosphorus, there was also about 1 per cent carbon. The metal in this case was very slowly cooled in the hearth of a basis open-hearth furnace.

When microscopically examined, the grains of the phosphorettic steel were found to be sheathed by envelopes of free $Fe_3P$ and $Fe_3C$, excepting in the regions of conjunction of three grains where the phosphide eutectic existed as a very coarse structure, easily resolvable with the aid of a simple lens.

On reheating the specimen to 1,100°, a temperature above

the melting point of the eutectic, and cooling in air, the envelopes of $Fe_3P$ were replaced by the characteristic eutectic, and when the piece of metal was completely melted and cooled so that solidification was effected in a few minutes, the crystalline grains were found to be surrounded by envelopes of phospho-eutectic.* We are forced to conclude that in the cooling of this metal in the open-hearth furnace at the point at which the temperature had just passed through the eutectic point the envelopes must have been eutectic. It is certain, therefore, that the segregation into envelopes of free $Fe_3P$ must have occurred when the metal was in a completely solid state.

The facts upon which this hypothesis is based have been repeatedly verified, and they prove that the eutectic when in relatively small masses in presence of a preponderating quantity of one of its constituents, when both constituents are in a completely solid state, and at a temperature below the melting point of the eutectic, yield up to the surrounding mass that part of it which is of the same substance as the mass.

It would appear, then, from what has been proved:

1. That there must have been migration of the solid constituents of the eutectic.

2. That the surrounding mass draws, by crystallic attraction through the walls of solid phosphide of iron, the enclosed phospho-ferrite, increasing thereby its own crystal growth, whilst the phosphide of iron coalesces or segregates into continuous and separate masses.

3. That if these hypotheses are correct, unless, which is improbable, the phosphide of iron finally and completely throws off the last traces of the phospho-ferrite which penetrates into it, it cannot be perfectly pure $Fe_3P$, but must contain in solid solution a small proportion of the interpenetrating substance, the quantity probably being dependent upon the rate of cooling after the segregation was more or less complete.

In considering the second condition of the eutectic when it is not in presence of masses of a free constituent it has been found that when the pure phosphide eutectic is annealed for many hours below the eutectic point, there is no separation into masses of

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* Photographic reproductions representing these changes can be seen in my paper on "Iron and Phosphorus," "Journal of the Iron and Steel Institute," No. II, 1900.

phospho-ferrite and phosphide of iron. It retains its characteristic form. As the constituents are equally distributed and close together, the attractions are equally distributed in every direction. Every particle of each separated constituent undoubtedly has an attraction for the nearest particle of the same kind, but they do not join for the simple reason that their attractions are balanced. They are in a condition of equilibrium. It is probable that were the equilibrium not exact segregation would at once begin, and if the heating just below the melting point were continued for a greatly prolonged period, complete segregation of the two constituents would occur.

There is now overwhelming proof that in solids, as in liquids, there is, what has been described by the late Sir W. Roberts Austen as intense molecular vivacity, and, that just as slowly evaporating liquid salt solutions tend to the growth of one single crystal of large mass, so in solids, under suitable conditions, there is a tendency for the parts of each respective constituent to join together so as to form a few large crystals of each. Like attracts like. This is really *one of** the causes of segregation in a solid. Probably one crystal larger than its fellows would, if time were afforded, induce by superior crystallic attraction all the smaller ones to unite with it for its own development. It is well known that this does occur when the mass is elementary and is composed of strongly cohering minute crystals. I have before me an instance in which millions of such crystals have moved and changed orientation to build up a single larger one. It is a piece of soft iron, which has been annealed at a suitable temperature for several years.

The original crystals had a diameter of about 0.02 mm., and the single crystal a cube volume of 80,000 sq. mm. From this data it is easily found by calculation that the single large crystal must have been formed at the expense and substance of 4,000,000 of the smaller crystals.

Professor Ewing and Mr. Walter Rosenhain have proved that rolled sheet lead even at normal temperature is capable of active molecular crystallic movement, and that the original minute

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* The words interpolated in italics have been added by Mr. Stead, as he says it is probable, as Professor Howe has pointed out in the last issue of *The Metallographist*, that surface tension plays an important part.

crystals rearrange their relative orientation so as to build up a few crystals of much greater dimensions.

### Segregation in the Secondary Eutectic Pearlite

Having given instances of the segregation of the constituents in normal eutectics, we must now pass on to consider the eutectic which is formed in solid steel at a temperature far below the melting point of its component parts or constituents.

It was Dr. Sorby of Sheffield, who, over 30 years ago, discovered that annealed and slowly cooled steels contained two constituent parts in thin curved plates, and that this compound constituent, after polishing and etching, even without any magnification, had the peculiar colored appearance of mother-of-pearl, an optical effect caused by the interference of light by the slightly projecting edges of the juxtaposed and curved laminæ of the cementite ($Fe_3C$). On account of this peculiarity Dr. Sorby described it as the " pearly constituent " of steel.

Almost all eutectics, whether primary or secondary, when polished and etched, if their structure is fine enough and not too coarse, give the same pearl-like appearance.

In pure carbon steels the pearlite proportion of carbide of iron and free iron are somewhere about 13.3 per cent $Fe_3C$ and 86.7 per cent Fe. When steel containing these proportions is slowly cooled from 900° C. to a point a little under 700° C., the carbide and iron, originally mixed together, constituting a homogeneous mass, separate into bands or laminæ which are alternately arranged, and co-incidentally there is a great evolution of heat. The steel when cold consists entirely of pearlite.

If either the carbide of iron or iron is much in excess of the pearlite proportion the cold steel contains the excess of either one or the other, as the case may be, in the form of free carbide or free iron, readily seen in the polished and etched steels.

If any of such steels are suddenly quenched at a point just above the critical temperature at which separation occurs pearlite does not form, and the parts containing the carbide on etching yield a practically homogeneous surface very minutely crystalline. This constituent called " hardenite " is now generally accepted to be a solid solution of carbide of iron in some form in iron. Prof. Arnold was first to show that it has approximately the composition represented by $Fe_{24}C$.

On account of the great similarity in behavior on cooling of the solid solution, of solid carbide of iron and iron, and of the alloys in liquid solution, the compound constituent pearlite is now generally regarded as a eutectic, although the original definition of Guthrie cannot in strict accuracy be applied to it, hence my suggestion to call it a secondary eutectic.

There is a great similarity in the relative fineness of the constituents of the two classes of eutectics according to whether the period they take to form is rapid or protracted.

Just as by very slow cooling through the eutectic points in the primary eutectics, the constituents become coarse and relatively wide apart, so under like conditions the laminæ which form in the secondary eutectic pearlite are coarse.

This close relation, however, does not stop at the eutectic point, for exactly as the constituent of isolated particles of the eutectic in phospho-iron eutectics exhibit extraordinary active molecular vivacity at temperatures below the eutectic point, so also a similar activity occurs in the cementite and iron in the pearlite of steel, more particularly when in the presence of free or massive ferrite (Fe) or cementite ($Fe_3C$).

Very marked instances of molecular movement are afforded in bars of pure Swedish iron which have been carburised by the cementation process. In the economical conduct of that process the quantity of iron cemented at one operation is considerable, and the cooling is necessarily correspondingly slow, consequently there is ample time for active molecular movement after the critical point has been passed. The period of passage through the eutectic point being also slow the pearlite is invariably comparatively coarse in structure, well defined, and easily resolvable under the microscope.

It is a fact, however, that no matter how slow the passage through the critical range, if the cooling afterwards is rapid, there is no sensible secondary segregation of the eutectic constituents.

I cannot proceed without referring to the series of excellent drawings of cemented bar by Prof. Arnold and Mr. McWilliams ("Journal Iron and Steel Inst.," 1898, No. II, p. 185), and the descriptive paper on the microstructure of the cold steel, as it is a standard contribution to our knowledge of the cementation process. The results are not only confirmatory of my own work,

made previous to the publication of their paper, but they have been repeatedly verified by my more recent researches.

This paper contains abundant proof of what I had previously found, that in such material if the eutectic equilibrium does not exist in the mass as a whole the free constituent which is in excess behaves exactly like the free phospho-ferrite in the phospho-iron eutectic. It apparently attracts that part in the eutectic which is of its own kind, and leaves the $Fe_3C$ or Fe to coalesce and segregate by similar attraction. It is very rare to find complete segregation, excepting when the amount of pearlite in proportion to the ferrite or iron is small. If the proportion of pearlite is only five per cent segregation is frequently complete. With 10 per cent to 50 per cent it is only partial. When the whole mass is entirely pearlite there is also partial secondary segregation, for by continued heating at a point just below $Ar_1$ the lamellar cementite is changed into the granular variety, but the particles are equally distributed. On the other hand, when there is an excess of from 5 per cent to 12 per cent of cementite, it appears to attract or draw a portion of the cementite from the pearlite, leaving the ferrite or iron in free broad masses adjoining the thick bands of cementite, and the whole of it if the cells enveloped by cementite are small.

It would certainly seem that the reason why segregation is more pronounced when small quantities of pearlite are present than in cases where it exists in greater quantity, is because the time in cooling in the cementation furnace, which is quite sufficient for the segregation and migration of the constituents of minute particles of pearlite, is not long enough for the completion of segregation of bodies of greater dimensions, the centres of which are further removed from the external attractive forces.

There is every reason to believe that if the steel just below the critical point were to be retained at that temperature for an infinite period, segregation of the larger masses of pearlite would result eventually, but that the nearer the composition of the whole mass approaches that of the eutectic, the greater the length of time which must elapse before the completion of the segregation.

No. 5 represents a photograph of a cemented bar polished and finally "polish etched" on leather moistened with picric acid, a reagent which if the pressure on the polishing block is

not too great leaves the iron brown and the carbide of iron or cementite brilliantly white. The white parts, therefore, represent the latter, the black parts represent the iron or ferrite.

The outer more highly carburised parts of the bar (carbon about 1.2 per cent) consists of almost completely segregated $Fe_3C$. It is known with certainty that when steels containing 1.2 per cent carbon have just passed through the critical point the cell masses consist entirely of pearlite and are surrounded by envelopes of free cementite. We are, therefore, justified in concluding that such was the case in this bar, but we see that the cell masses do not contain pearlite. They consist essentially of
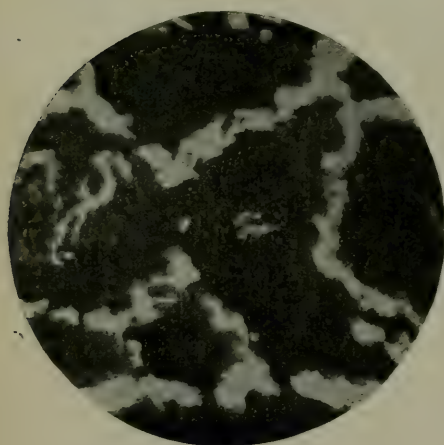


No. 5 ×80.—Cement Bar. Dark Part, Iron; White, Fe₃C.
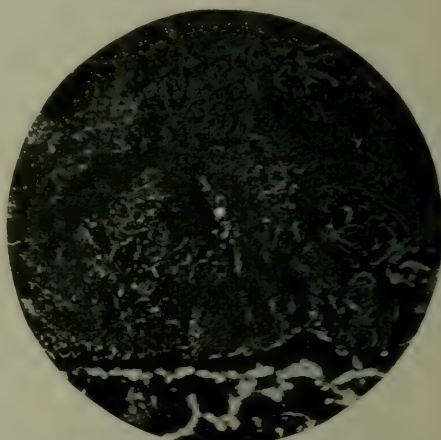
No. 6 ×80.—Cement Bar. Dark Part, Iron; White, Fe₃C.

free iron, excepting in the centre of some of the larger cells where a little pearlite is present. The only conclusion we can form is, that the original fine cell walls of $Fe_3C$ existing just before the steel cooled through the critical point $Ar_1$ must have by crystallic attraction drawn to itself, at a temperature below the critical point, the carbide from the originally formed pearlite, leaving the ferrite in the free state, and that where the cells were of very large dimensions the attraction from the more distant cell walls was not sufficient in the time afforded to completely remove the carbide, hence some pearlite still remains.

No. 6 photo represents a cemented steel in which the central

part consists of pure pearlite or laminæ of carbide of iron and free iron in equal distribution. The external part is more highly carburised, and consists of cells of ferrite with a little pearlite in the centre of some of them surrounded by thick cell walls of cementite. The heat treatment of both inside and outside, of course, must have been identical. The equilibrium of attractive force in the pure pearlite is undoubted, and it remains as it was left after passing the critical point; there is no marked secondary segregation, but in the outer layer of steel, the carbide being in excess, there is no equilibrium, and being in excess it has drawn to itself the carbide from the cells, leaving practically pure iron behind.

## The Secondary Segregation Range

I now pass on to describe a method I have used to ascertain the temperature at which the secondary segregation in pearlite is most active.

The method I refer to is that of heating the bars of steel to a high temperature at one end only, so that there is complete range of temperature between the hot and cold ends. When two such bars of sufficient length are placed close together in a muffle furnace, and are kept in that position for an hour or several hours, it is easy to determine the temperature at every part of them by means of a Le Chatelier pyrometer. In practice the couple is placed at the points where the curved sides of the bars are in contact, and it is steadily drawn from the hot region towards the colder ends. The distance from the terminals of the bar and the recorded temperatures are carefully noted. After heating for the desired period, the bars are removed and allowed to cool in the air, or may be quenched in water, as the case may require, and are then either cut or ground down, polished, etched, and their structure noted.

By this means, in one single piece, may be obtained a complete gradation range, in which there is a correlation of thermal treatment and microstructure. When such bars of carbon steels are simply polished perfectly or roughly, and are then immersed in dilute nitric acid, the critical point $Ar_1$ or $Ac_1$ is indicated with exactness, especially if the bars were quenched in a cold liquid or even if cooled rapidly in the air, for at a point on each bar directly below the critical point the action of the acid leaves

a line or area almost white. Above this line the steel assumes
a black or dark brown color, below the line it etches out dark,
but not so dark as the portion above.

The microscope when applied to the examination of the per-
fectly polished and etched sections shows that the very black
area, in the cases where the bars are quenched, contains hardenite,
the constituent of hardened tool steels, but if the bars are small
and are cooled in the air, the hardenite is replaced by the transi-
tion conditions intermediate between the hardening condition and
pearlite, but these also etch out dark colored.



No. 7.—Bar Steel.  Natural          No. 8 × 500.—A Pearlite Area in a Steel
   Size.   Heated at one end.            with 0.47 per cent Carbon.
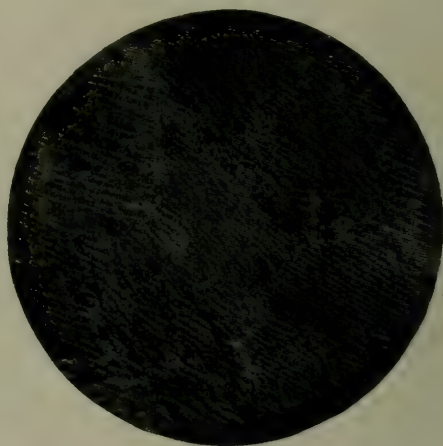
The temperature corresponding to the upper dark border of
the white line in pure carbon steels is close upon 690° C., it is in
fact the critical point $\dfrac{Ar_1 + Ac_1}{2}$.

The white line is the result of segregation of the cementite
and ferrite.

The area where there is most pronounced segregation closely
adjoins the critical point, but it is continued for a distance of 2
or 3 mm. below it, gradually diminishing with the distance.

In the trials I have made a constant temperature was main-
tained for at least 6 hours, in some cases 70 hours.

The samples exhibited show in a very clear manner the

well defined white line where crystallic attraction and solid migration of solid through solid has been most pronounced.

Photo No. 7 represents one of these bars.

One sample has not been etched, but has been left simply polished with fine emery paper. It is bright from end to end, but on placing it for 10 seconds in a 20 per cent solution of nitric acid in water, the end originally most highly heated, down to the critical point $Ar_1$ becomes dark brown, and in marked contrast to it, there is a white line, immediately below, diminishing in whiteness for 2 mm. as the distance from the critical point
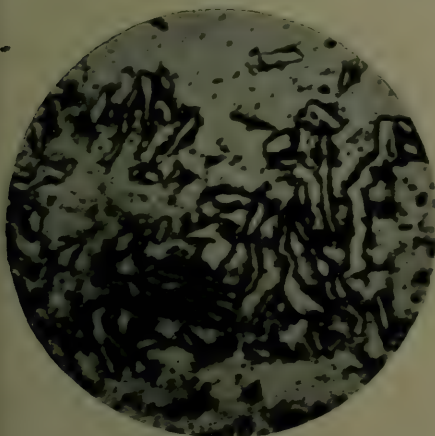


No. 9 × 500.—The Pearlite of No. 8, after Long Heating at 670°C. Segregated Cementite and Ferrite.
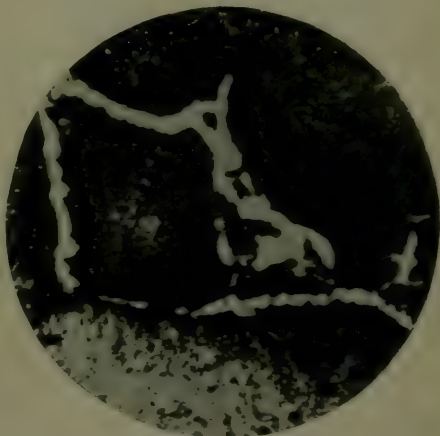
No. 10 × 500.—Soft Steel. Very Slowly Cooled. White Bands, $Fe_3C$; the rest is Iron.

is increased, beyond which the steel surface has a uniform gray color.

Photo No. 8 represents a pearlite area in a bar containing 0.47 per cent carbon, cooled down with liquid slag, magnified after etching with iodine 500 diameters. The laminæ of ferrite and cementite are comparatively fine.

Photo No. 9 is a similar area in the same piece of steel after long heating at just below the critical point $\dfrac{Ar_1 + Ac_1}{2}$.

The bands or plates have now disappeared, and have been replaced by irregular masses of cementite. This represents and explains the reason why the band is white in photo No. 7.

Photo No. 10 represents an area in steel containing 0.1 per cent carbon, which has been very slowly cooled. The segregation in this case was complete. The white irregular-shaped areas are cementite, the dark background ferrite containing traces of diffused carbide.

### PRACTICAL OBSERVATIONS

It is satisfactory to note that in this research the results are of some practical value, for it will be obvious that if steel when forged has the structure which experience shows is the best, and it is only desired to make it of maximum softness by annealing, that the prolonged heating to temperatures above the critical point is only time and fuel wasted, for the maximum softening is effected when the steel in cooling passes through about 20° C. below $Ar_1$, or from 690° C. to about 670° C. It must not be understood from this remark that it is advocated to anneal castings and forgings at such a low temperature, for one of the effects aimed at in practical annealing is not so much to soften as to break up a pre-existing coarse structure, and this can only be done by heating to much higher temperatures.

Neither is it advisable to prolong the heating just below $Ar_1$ in the annealing of the purest and softest steels containing little carbon, for they are liable at that temperature to develop coarse crystallization and consequent brittleness.

If the steel is held at high temperatures above the critical points and is not cooled slowly afterwards there will be no softening effect. It is clear, therefore, that a comparatively short heating at a temperature where the segregation is most profound will be much more efficacious in producing the softest possible condition than a much longer heating at either higher or lower temperatures. Maximum softness, however, is only required in steel in exceptional cases.

When a high elastic limit is required with a good and safe elongation the heating at the point represented by the white band in photo No. 7 should be avoided, for segregation of the cementite means a reduction of the elastic limit and tenacity.

All my metallographical experience points to the necessity of retaining in finished forgings the carbolic in a diffused state, not in the hardened form, if a combination of the best properties are aimed at, and, therefore, the segregation range should be

passed through as rapidly as possible, and the structural steel after being heated through the critical points $Ac_3$, a temperature sufficient to cause as complete diffusion of the carbon as possible, should be cooled down rapidly to about 600° C., and be then allowed to cool in air, or, in some cases, the steel after heating may be quenched outright, and be reheated to a temperature below the segregating range, and cooled in either air or water from that temperature.

If the structure of the steel originally is very coarse a double heating is advisable to effect a perfect distribution of the carbon, and after the second heating the treatment should be the same as just described.

Treatment of this kind leads to the carbon condition being in that state called by M. Osmond " sorbite."

Steels which have been subjected to negative quenching, that is to say, moderately rapid cooling, such as oil quenching, or cooling in air, or which have been quenched in water and reheated to about 500° C., are almost all highly sorbitic in character.

Such sorbite steels, according to my own experience, are stronger and less liable to break down under continued fibre stresses than less sorbitic material.

## Summary and Conclusions

The evidence appears to clearly show, viz.:

1. That at certain temperatures near to, but below the eutectic point of the iron-phosphorous eutectic, the two constituents when quite solid are capable of migrating from one part to another.

2. There is evidence that the large crystalline masses in solids have an attractive force for the smaller particles of the same kind, and under suitable conditions draw them to themselves. This force I have called " crystallic attraction."

3. That in the ordinary or primary eutectic referred to, if the whole mass is of eutectic composition, the constituents being equally distributed and in juxtaposition, the attractions are balanced, and as long as the condition of equilibrium is maintained there is no segregation, at least not during heating for 48 hours, to a point just below the eutectic melting point.

4. That active secondary segregation occurs when the

eutectic exists in isolated areas and is surrounded by masses of substance of the same kind as one of its constituents. As there is no equilibrium or balance of the crystallic attractions between the particles of a like kind, both constituents draw together or segregate and cease to be eutectic in character.

5. That in the secondary eutectic pearlite, at temperatures below the eutectic point, there is the same tendency for the constituents to migrate and segregate. A bar of steel heated at one end to 900° C. and kept cold at the other end for many hours, after polishing and etching with dilute nitric acid, reveals a white band just below the critical point, an appearance caused by the segregation of the cementite into relatively large masses.

6. That heating steel at the temperature represented by the white band — 690° C. to 670° C. — most rapidly produces a softening effect, and that in practical annealing, when the steel in cooling slowly passes through this zone, the main softening effect is produced. It is, however, the zone in which the elastic limit of the steel is most rapidly reduced.

## POSTSCRIPT.*

The facts in this paper are believed to be substantially correct, but it is possible that after more research the interpretation of the phenomena may require modification. For instance, it is possible that the force which draws separate particles together in solids may be other than a simple crystalline one. The genesis of the development of crystals in solids requires more research.

Surface tension undoubtedly plays an important part in determining the form of some infantile crystalline masses.

The crystalline force which determines the angles and faces of some free growing microscopic crystals is dominated by that of surface tension. It would appear that this is the case with carbide of iron in steels heated to just below the lower critical point. The plates are broken up and by the force of surface tension assume the form of more or less perfect spheres, or the plates coalesce in the direction of the surface planes as shown in photo No. 4.

This globular development appears to be a primary stage

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* Written for *The Iron and Steel Metallurgist.*

in the formation of carbide of iron crystals. It is believed, however, that if time were given for the crystal masses to coalesce to a sufficiently large size, idiomorphic crystals of $Fe_3C$ would eventually result, but with angles always more or less rounded by the force of surface tension.

It is quite possible that heating at temperatures just below the critical point may need to be maintained continuously for many months and possibly years to admit of this. The writer has already placed several bars of steel into position and after continuously heating at temperatures between 600° and 700° for 12 months will be removed and examined. It is only by experiments of this kind, which have been conducted by Messrs. Heycock and Neville in their research upon the constitution of copper-tin alloys, and by the author on steel and iron-phosphide alloys that we shall eventually arrive at the truth.

In the case of phosphide of iron it is possible that idiomorphic crystals of $Fe_3P$ do form when there exists small particles of the eutectic in the presence of an excess of iron containing phosphide in solid solution, and when the heating is below the melting point of the eutectic. Photo No. 3 seems to indicate that such is the case and that, therefore, the crystallic force of $Fe_3P$ is greater than that of its surface tension. There is, however, a doubt as to whether what appear to be idiomorphic crystals of $Fe_3P$ are pseudomorphs produced by the crystallization of the surrounding enveloping mass, and that the $Fe_3P$ is compelled by what possibly is the superior force to deposit between the cleavage planes and assume the crystalline form of iron instead of that of the phosphide.

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## MALLEABLE CAST IRON *

### By RICHARD MOLDENKE

WHATEVER may be the scientific definition of a malleable casting, for commercial purposes it is one made of iron of special composition and rendered malleable by subsequent annealing. The composition of the hard casting lies between well defined limits, and it is affected by so many conditions that the

* Paper read at the Milwaukee meeting of the American Foundrymen's Association.

successful production of this class of work is one of the most difficult branches of the iron industry.

While nominally the composition of a good malleable casting is but little different than that of a car wheel or a roll, yet the fact that it can be twisted, bent and hammered out hot or cold and has double the tensile strength of these products shows that the constitutions of the castings are quite different. This difference in the constitution may be traced to the condition of the carbon in each. In the ordinary gray iron casting we may have some 3 to 3½ per cent graphite present. In the malleable casting we have the same amount, weighed as graphite in the analysis, but radically different in its characteristics. This form of carbon due to the annealing process has been called temper-carbon by Professor Ledebur, who first described it in connection with the malleable (Ger. " temper ") process. I will mention one of the peculiarities of this form of carbon. If a malleable casting which on fracture shows the fine black velvet surface, is heated up very high and then plunged into water all this amorphous carbon is dissolved, and the fracture shows the grain of a good tool steel. The same is often seen when a piece is hammered cold, and more especially when a casting that has become warped is heated up and straightened. The grain in the latter instances will not be as good as in the first one, but it shows that to straighten a malleable casting no heat, and preferably pressure only, should be applied. This characteristic of the carbon is often used to palm off malleable castings as steel ones, much to the disgust of the user and the producer of bona fide " malleable."

Of the properties of the malleable casting, it may be said in general that the tensile strength should run between 42,000 and 47,000 pounds per square inch. Castings showing only 35,000 pounds are still quite serviceable for ordinary work. It is not advisable to run much beyond 54,000 pounds per square inch, for the resilience is then reduced, and one of the most valuable properties of the malleable casting impaired. I have made much work running up to 63,000 pounds by the plentiful addition of steel to the mixture in the open hearth furnace. I do not, however, recommended this, as wherever such high results are wanted, they can best be obtained by using the steel casting direct.

As an instance of what can be done with malleable castings I will mention a series of tests made with bars of small and large

diameters, which were heated and carefully drawn out under the hammer. While the interior, or high carbon portion was badly cracked up, the surface was of such a fine material that in one sample the tensile strength actually ran up to 123,000 pounds per square inch.

The elongation of a piece of good "malleable" will lie between 2½ and 5½ per cent measured between points two inches apart. The thicker the piece the smaller the elongation.

In making the transverse test, the deflection of an inch square piece, resting upon supports 12 inches apart, should be over one-half inch, the breaking weight being at least 3,500 pounds. Very soft iron often deflects 2½ inches under this test, but this is exceptional and may not be reproduced continuously.

The high resilience, or resistance to shock, in "malleable" is its most useful characteristic. It is well known in railroad circles that the ordinary steel casting comes nowhere near the malleable for service conditions. Only where an exceedingly high tensile strength is required, as in the car couplers for the heavy modern trains, is the malleable casting being gradually replaced. On the other hand, car castings, formerly made of gray iron, are now specified for malleable wherever possible, in the interest of greater strength and reduced weight. When we remember that the present production of malleable castings is at the rate of 650,000 tons per annum, and that at least half of this goes into car construction, the importance of the industry may be properly understood.

In spite of this enormous production, there is really little information available outside of the foundries most interested, and it may as well be said, also very little within. The founder is not going to increase the difficulties in his sales if he can help it, and the inspecting engineer, not being able to check the process from his own understanding, cannot act as intelligently as he really should. The American Society for Testing Materials is, however, at present at work on this very thing, and we shall soon have a set of specifications governing the production of these castings where good qualities are essential, which will insure better work all along the line.

Before going into the composition of good malleable iron it is necessary to look a little into its structure. Originally cast to be perfectly chilled, that is with the carbon all combined, and a contraction of about one-fourth inch to the foot, the annealing process

serves to expel the carbon from its state of combination, depositing it between the crystals of the iron, not in the crystalline graphite of the gray iron, but as an amorphous form not unlike lamp-black. At the same time an expansion equal to half of the original contraction takes place, the net result being a shrinkage allowance for the pattern identical with that for gray iron castings of similar shape and thickness.

Beside this expulsion of the carbon from its combination, there is a removal of some of it from the outer portions of the casting. This amounts to nearly all in the skin to nothing one-fourth inch inward. I do not take kindly to the generally accepted theory that oxygen from the packing penetrates the casting, remov-ing the carbon by burning it out. I have always found that when oxygen has access to the interior, through the open structure of the iron itself, this is also oxidized with the carbon, and the whole presents a sorry sight. Whether, however, carbon diffuses out or not, in a good casting, I cannot say, and hope that this point will some day be taken up and settled by careful experiment.

It will be noted that owing to the removal of varying amounts of carbon from the skin to the interior no carbon determination of a malleable casting is of any value, unless the sample is taken before the anneal, and even then it is only good for the total car-bon. For an annealed piece a sample taken from the centre of the fracture with at least three-eighths inch untouched around the drill would give a fair indication of the carbon contents, but cannot claim accuracy.

In former days of charcoal iron about four per cent carbon was the rule in malleable castings. In these days of coke irons and steel additions to reduce the carbon, this may run as low as 2.75 per cent before trouble ensues in the anneal, if not already in the foundry through excessive cracking and shrinkages. With the modern demand for a high tensile strength it is well to place the lowest limit at 2.75 per cent and the upper limit for common work would be found in the saturation point of this grade of iron, or 4.25 per cent. It is absolutely necessary that the hard casting be free from graphite; even a small amount of this indicates an open structure with consequent ruin to the work in the anneal from penetrating oxygen. To keep the carbon in the combined state is the function of the silicon percentage arranged for in the

mixture, the rate of cooling due to the cross section, the pouring temperature, sand, etc.

The sulphur content is quite important, especially just now when we are getting the sweeping of the coal mines for our fuel to a greater or less extent. The percentage should not be allowed to go over 0.05 per cent, though double this may let a casting pass muster where good work is of no special object. Once the sulphur exceeds 0.05 per cent trouble may be expected. It is, therefore, wise to hold the pig irons below 0.04 per cent and to see that the fuel used is not too rich in sulphur.

Manganese is seldom troublesome, as it does not often exceed 0.40 per cent in the mixture, which means 0.10 to 0.20 per cent in the casting. Above 0.40 per cent in the casting it begins to give trouble in the anneal and therefore manganese as a general proposition should be kept low. Phosphorus should not exceed 0.225 per cent and is better kept below this.

To get the proper silicon limit for the class of castings to be made is the trick which means either success or failure for a foundry. This will be realized from the fact that we do not know how the castings will come out until about a week after they went into the anneal. Now suppose the mixture is wrong, and the silicon is either too high which means " low " or rotten work, or too low in the castings, making them " high " (strangely contradictory, but nevertheless shop terms in daily use and dating back to the times when silicon was unheard of in malleable works), this means hard burnt white castings stronger than the first mentioned class, but equally undesirable. We do not know of this until a whole week's work, in all probability equally bad, has been placed in the ovens, and comes out in its turn only to wander into the scrap pile. Naturally disaster stares the inexperienced founder of malleable castings in the face all the time, and only a good laboratory will keep him out of hot water, everything else being equal. It also shows the necessity for better protection to the buyer, who cannot be supposed to distinguish between a good and only fair casting.

In general we may say that the thicker the casting the lower the silicon allowable in order to get a white iron in the sand. Thus for the heaviest classes of work, the silicon of the casting should not exceed 0.45 per cent. For ordinary work 0.65 per cent is the point to be sought for. Agricultural work may run

up to 0.80 per cent, while the lightest casting may have 1.25 per cent without danger, though it is not advisable to exceed this limit for anything.

Our American practice differs from the European in several respects. We have a comparatively short anneal, that is we aim at a conversion of the carbon rather than its removal. Over there it is desired to get all carbon out, so that a wrought iron casting, if it may be so called, may result. With much of the iron cast from crucibles, it is quite possible to make very fine grades of work, and this may account for higher prices for malleable than steel castings paid in some parts of Europe. Imagine, however, what would result if we were compelled to employ the crucible process here, with an average production of 35 tons daily in the larger plants, or about 80 tons in the very large ones.

The common American practice is to use the reverberatory, or " air " furnace, either with or without the top blast over the bridge to hasten the melting. There is always a blast introduced under the grates, unless indeed in our older works, the chimney draught is exceptionally good.

About 12 years ago the open-hearth furnace was introduced into one of our largest works, and it was my good fortune to gain experience with it there. While not many malleable establishments have the open-hearth furnace (I can count three on my fingers), yet it is undoubtedly the most economical melter there is, provided several things are observed. One is that it must be kept busy as much as possible, as only then its full economy is taken advantage of. Then skilled workmen must be kept in charge. This does not mean the steel melter, with his habit of letting the heat take care of itself, and tapping a ten-ton heat five hours after charging, whereas it should come out in two hours and a half, but it means a man who will use his muscle freely to rabble up the heat, push the pigs into the bath as quickly as they can be cared for, mix his iron well, fire sharp and quick, so that the process becomes one of melting only, rather than a refining or burning out of large quantities of silicon and carbon. When these conditions prevail, the open hearth will prove a friend indeed and turn out a most excellent product.

Let us take fair conditions with three heats daily from a ten-ton open-hearth furnace. Using producer gas the fuel ratio is about one of coal to six of iron. In the reverberatory furnace

the fuel ratio is one to four at best, and often only one to two. It is not advisable to make larger heats than 15 to 18 tons, as the time consumed in melting, and especially in pouring from the small ladles after tapping becomes so great that the bath is seriously damaged by undue oxidation and overheating. When the time comes for continuous melting in the malleable foundry, when heat after heat is taken off as fast as the bottom can be patched up and the furnace charged again, then will the complete economy of the open-hearth furnace be fully realized. We may then also see the tilting furnace of value to us, though a device of my own, which I am using successfully in my own interests, and which allows the tapping from three spouts at different levels, successfully, has the advantages of the tilting furnace for malleable iron without incurring the heavy first and running costs.

For making malleable castings, the open-hearth furnace should be pushed very hard for a time almost sufficient to collapse it, then it should be checked before actual damage is done to crown and ports. In this way a short, sharp heat is obtained, the silicon of the heat may be calculated for a loss of 20 to 25 points, whereas from 35 upwards is the rule in other processes. Three hundred heats should be taken off before repairs of several days' duration are required, and a total of at least 1,000 heats only should necessitate practically a rebuilding with but little loss other than the refractories.

In the meantime there has been much improvement in the air furnace. Strange to say, while the quantity of metal, the composition, excepting only in the phosphorus content, of the large roll and the malleable casting is the same, the air furnace used in each industry has been developed on different lines. In making rolls we find the short high reverberatory chamber, more on the lines of the copper furnaces, while in the malleable industry the furnace is long, very low, and contracted at the stack entrance. While formerly the hearth was practically rebuilt after each heat, at the present day several heats are taken off before a new bottom is made. The bungs, of course, always suffer, and herein the crown of an open hearth is much more easily cared for. But the poor efficiency of the fuel is an inherent difficulty which cannot be overcome, and presents new difficulties with every change of quality.

At the present time there is a general difficulty with the

coal used, which means castings with an undue amount of sulphur. These castings are weak and will some day wander into the scrap pile. When the next slump comes we will be confronted with a serious condition. This high sulphur scrap will come into the market, in fact forced upon the founder wherever his castings can be identified. They will be hard to use by him, from the fact that high sulphur material will not be available for basic steel, as was the case formerly. There is then a neat problem, and one which will make the fortune of anyone who may discover an economical remedy, and that is the removal of sulphur from iron on a commercial scale. I present this to our experimenters and wish them success with it.

The cupola still turns out a considerable tonnage of malleable castings, but this process will be gradually superseded by the furnace method, chiefly on account of the better grade of work turned out by the latter. There is, however, one interesting point connected with the cupola process, or rather with cupola iron, which we must go into more fully in connection with its bearing upon the anneal. Cupola iron requires some 200° F. more than furnace iron to anneal it properly. This is a general proposition. It seems strange that it should be so, but possibly the structure of cupola iron is so close that it requires more effort to get the crystals apart and to effect the liberation of the carbon from its state of combination. Whether this is due to the contact of the metal with the fuel as it trickles down in thin streams and drops is hard to say, but the difference certainly exists and must be provided for in the anneal.

Naturally with a higher degree of heat the wastage of the annealing pots is more marked, and the process becomes more expensive in this regard also, for our annealing boxes must be reckoned as a dead loss which is to be diluted as it were by as long a life as possible in the ovens.

In studying the annealing process we find two extremes leading to about the same results so far as the carbon change is concerned. A short anneal at a very high heat is as effective as a comparatively long anneal at a much lower temperature. That is to say, we can anneal, or rather change the carbon in a casting by placing it over night in a melting furnace which has been let cool below the melting point of the iron, or do the same thing in the annealing oven at a much lower temperature but giving

it a week's time. Of the two methods the latter is by far the preferable, as it not only permits the change in the carbon, but also gives the carbon time to get out. Then again the chances of burning the castings in the anneal are obviated. The result is a good, reliable casting, while in the hurry-up process one never knows whether they are annealed at all. Sometimes they are and often they are not. Malleable founders, therefore, while experimenting for generations on short annealing lines, have come to recognize that the best all-around and safe method is to arrange matters so that an oven may be regularly recharged on the same day of the succeeding week.

We may describe the annealing process by a curve which runs up quickly, remains horizontal for a short time, and then drops very gradually. That is, a sharp heating up, in the shortest safe time possible, then a shutting off of the dampers and maintaining of the temperature evenly for a period of say two full days at least, and then a gradual cooling down to at least a black heat before dumping. Here is where mistakes are often made, annealing pots being drawn red hot because some particular casting is wanted in a hurry. The castings are red hot when the air touches them, the delicate reaction of the carbon is disturbed and an inferior material results. I have always had softer, more malleable iron from the anneals which had the extra Sunday to become cold in the oven, and were cold when dumped on Monday morning.

An oven can be brought up to heat as quickly as may be, the fuel waste to do this being alone considered. In cities where the smoke problem exists, more time is required than in the open country. For a fair-sized oven at least 36 hours are required to bring it up to heat (a pyrometer should always be used to test this), and then it should be held there.

As to the actual temperatures there is this much to say. Furnace iron of average thickness must have received over 1,250° F. after coming up, until cutting off the heat, to be safely annealed. Perhaps even then some of the work must be put back for another anneal. A safer limit is 1,350° F. and no more is necessary. This temperature must exist in the coldest part of the furnace, or usually at the lower part of the middle in the front row pots. As a rule the upper space of an oven is some 200° F. higher than this, although I have succeeded in building

ovens in which there was but a difference of 100° F. throughout the whole interior space.

Translating these temperatures we find that 680° C. is the lowest point for successful annealing of furnace iron, while 780° C. is the safest one. For cupola iron the temperature should be about 850° C.

If we contrast former times with the present, in the malleable industry, when charcoal irons only were supposed to chill, when immense piles were kept at the command of some melter who had inherited the art of looking wise over the test plug, where would we have been to-day when the importing of foreign irons is the order? In dollars and cents the benefit of science to the much neglected foundry industry has been incalculable, and perhaps the malleable foundry has received the greatest share, as it needed it most.

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## INNOVATIONS IN MARTIN FURNACES *

### By LUDW. UNCKENBOLT

AS Schoenwaelder has shown some time ago in his patent, the proportionately short duration of the Siemens reverberatory furnace, working with high temperatures, especially the Siemens-Martin furnace, Glass furnaces, etc., rests upon the fact that the draught which brings the gas and air from the regenerator chamber to the furnace and from there takes the products of combustion through the regenerator chamber to the chimney, causes it to undergo an unequal strain. Therefore, the furnace does not have the same degree of heat everywhere, begins to wear in certain places, and finally burns through, while other parts of the furnace remained almost unharmed. The truth of which is clearly shown by the breaking of the furnace.

Some time ago Schoenwaelder had overcome this difficulty by dividing the regenerator lengthwise, and supplying it with especial supply canals, in which latter slides of refractory material were arranged. Through the opening and closing of these, Schoenwalder could observe the point of greatest heat in the furnace, when he so desired. In the beginning and middle of the nineties the Schoenwalder patent attracted much notice. To-

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* "Stahl und Eisen," November 15, 1903.

day one no longer speaks of it. A great difficulty of this plan was that its introduction into practice was joined with a relatively high cost, and that the 8 to 12 slides very easily jammed fast and could not be moved, and therefore naturally the advantages of the arrangement were lost.

An invention made by Jules Puissant d'Agimont is designed to remove the difficulty just mentioned by increasing the duration of the Siemens reverberatory furnace and by bringing about a greater surety in the working of the accompanying regenerating plant.

For this purpose Engineer Puissant arranges in the ascending draught *a* (Fig. 1), likewise in the canals which lie between



Gas          Air          Air          Gas
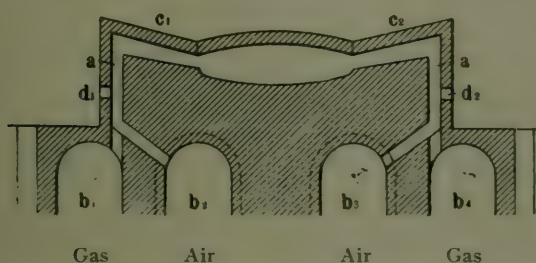
Fig. 1

the regenerators $b_1$, $b_2$, $b_3$, $b_4$, and the top of the furnace, $c_1$ and $c_2$, the openings $d_1$, $d_2$, etc., which can be easily and quickly opened and closed by very tightly closing valves, having a cover of sand or water, and by slides, etc. Since all the Siemens-Martin furnaces work with chimney draught, the entrance of the outside cold air can be produced through the opening of the valves, etc., and it is possible in this way to cool that part of the furnace situated between the open valve and the chimney quickly, easily, and thoroughly. In this way one can transfer the point of greatest heat in the furnace, the draught, and the chamber, quickly from left to right, from the front to the back, or inversely, and so keep the furnace at a temperature continually becoming more equal. The wear is more equal and therefore this costly furnace lasts considerably longer.

It is best to open the valves always on the side of the furnace where the gas is drawn off; for by the opening of the valves on the side where the gas enters the furnace, the bath would be

cooled, which is not at all intended. The cold air, as is known, presses continually downward, and the cooling in the furnace would extend upward by degrees to the arch. By the other method, however, the gas and the air stays in the heating chamber under pressure and this pressure must be removed. For example, the valve on the entering side is opened. Then the hot air will push out of this opening with force, and gradually the difference of pressure will be equalized. On the side where it is drawn off it never pushes up in the furnace in this way. If one



Fig. 2.—Martin Furnace at Hautmont Furnished with Puissant Patent.

were to open it freely here, the chimney would immediately draw the cold air, and would cool the chamber lying behind it, quickly and thoroughly. The innovation has for some months been tried at the Providence works in Haumont, France, at two Martin furnaces, and so far has proved successful, and is open to inspection to those interested. Figure 4 shows a Martin furnace at that place furnished with the Puissant patent. The device is set up with little expense, and its construction is easily undertaken during the rest of a Sunday. The curved parts of the cast iron, etc., are simply screwed on to the furnace fastenings, — or are

fixed behind the bands of the bracing. With this device of Puissants, no means is provided for making the regenerating furnace durable. Just as before, it is necessary to have a good, careful smelter, and good refractory stone in order to reach great durability. The Puissant patent can indeed be of great advantage in the hands of an intelligent smelter. To interest a smelter in this, a premium on the durability of the furnace might be offered, as in the Schoenwaelder. On the other hand, a premium for the economy of coal would guard against using this valve too freely; for every time the valve is opened it costs coal. This must be clearly understood.

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## DISTORTION AND RUPTURE OF IRON AND SOFT STEEL *

### By F. OSMOND, CH. FREMONT, and G. CARTAUD

THE purpose of the authors' experiments was to ascertain and to classify the various distortions exhibited by iron when iron and low-carbon steel are subjected to stresses; to ascertain, so to speak, the alphabet of its elementary distortions.

The most important contributions to the subject which we shall try to connect and to complete are those of Martens, Stead, Mugge, Ewing and Rosenhaim, Heyn, Ewing and Humfrey.

It is known that iron, cast or welded, is made up of polyhedric grains, generally equiaxial, which may be compared to the cells of organic substances. Each cell is filled with a crystalline form of *alpha* iron, crystallized in the cubic system, and whose orientation is constant in the interior of each cell. Finally, iron may be considered as amorphous, if we have in mind distortions so small that the structural elements may be ignored. It must be admitted that iron possesses simultaneously three structures, amorphous, cellular, and crystalline, which are all possible in inorganic substances. Each of these structures undergoes distinct distortions.

In amorphous bodies it is known that the distortions are controlled by geometrical laws. These distortions we shall call ordinary (*banales*) because they are common to all substances. In substances with a specific structure, the ordinary distortions are

regulated by the structure, cellular or crystalline, or both, giving rise also to *specific* distortions.

We distinguish in iron seven kinds of distortions, some of which are already known, while others are described here for the first time:

### A. Ordinary Distortions as Influenced by the Cellular Structure

1. *Microscopic folds* (*plissements*) perpendicular or parallel to the direction of the stress (already known in the microscopical condition). These folds, when the distortion has been carried on far enough, give rise, in the interior of the mass, to fringes (*franges*), described by Heyn, appearing alternately dark or bright, after etching, under the same incidence of light.

2. *Oblique folds* (*plissements obliques*), known in the microscopic condition as Lüders' lines, but new microscopically and of the same nature as the fringes.

### B. Purely Cellular Distortions

3. *Joints* between cells, already known.

4. *Cold-worked borders* (*Bordures écrouies*), more or less torn (*déchiquetées*), along the joints (not previously described).

### C. Purely Crystalline Distortions

5. *Cold-worked thorns* (*épines écrouies*), short, not previously described, generally connected with the joints.

6. *Cleavages p,* long since known.

7. *Neumann's Lamellæ,* known since 1848 in meteoric irons, observed in certain manufactured irons, but not hitherto utilized in their study.*

From our experiments and observations we arrive at the following conclusions:

*In the same steel,* other things being equal, the application of static efforts favors the formation of ordinary or cellular dis-

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* * In speaking of cellular or amorphous distortions, we have in mind the position and the form of these distortions, and we do not mean to imply that they do not also result, when taking place in a crystallized body, in certain intimate modifications of a crystallographic nature, but these are here of secondary importance.

tortions, prodromes of an ordinary fracture after considerable distortion; a blue heat, sudden blow, rapidly alternating stresses promote lines of crystalline distortion, immediate or ulterior, sudden, and without notable distortion.

*In different steels* the greater importance of crystalline distortions over ordinary or cellular distortions, is the more pronounced, and leads the more readily to intercrystalline fracture, the better developed the crystalline structure is. Other metals have a structure as complicated as that of iron, but, generally, the mechanical properties pertaining respectively to their superposed types of structure are of the same kind. In *alpha* iron, which constitutes essentially all the industrial irons and soft steels spontaneously cooled from a red heat, the mechanical properties pertaining to each structure are very different, even opposite.

Iron, as a cellular substance, is very plastic; iron as a crystallized substance is very brittle. As both of these structures are found, not separated in different samples, but superposed in the same sample, they give rise to facts contradictory in appearance.

In accordance with the influence of the methods of manufacture which may promote one or the other of these structures, and in accordance with the influence of the stresses which may affect one structure more than another, or prevent to a greater degree the effect of one of them, the fracture will be produced by considerable ordinary or cellular distortion, or by crystalline sudden distortion without previous deformations.

These are the properties which give to iron its peculiar position among materials of construction and explain the unexpected fractures sometimes occurring when implements of that metal are in use.

# ABSTRACTS *

*(From recent articles of interest to the Iron and Steel Metallurgist)*

THE Study of Iron Metallurgy at the Royal Technical University at Aachen. F. Wüst. "Stahl und Eisen," November 15, 1903. 8,300 w. — During the past ten years a complete revolution in the methods of production of iron and steel has taken place. But the training of iron workers or metallurgists has not developed at the same pace. Matters have practically come to a standstill. In 1863 there was only one professorship of metallurgy in all Prussia. In 1866 a new professorship was established in Clausthal, and, aside from that, there was only one professorship of metallurgy in the Technical Institutes at Aachen and Charlottenburg. So that very little progress has been made in the craft during several decades, despite the fact that several new processes were developed, and that the production of iron in the period was more than quadrupled. The progress made in the German iron industry has been chiefly through the leadership of men who have been engaged in the work long enough to be able to fill up the gaps in their professional and theoretical training. The chemical principles underlying the various processes are now so fully understood that the metallurgist is well prepared for his tasks on this side as soon as he is familiar with the chemical actions which take place, and on this basis can supply the necessary inferences, but on the mechanical side of the industry, conditions are quite different. Questions

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are constantly arising, the solution of which requires independent, creative work. An opportunity is given the metallurgist for developing his own ideas, because the mechanical processes are subject to quicker changes than the chemical. The metallurgist should have such a knowledge of mechanics and of the various kinds of motive power that he may know which is the most expedient to use in a given case.

Dr. Wüst recommends, in accordance with the above statements of conditions:

1. The extension of instruction in iron metallurgy proper by development of the chemico-metallurgical branch and the branch of mechanical construction.

2. Limiting of chemical instruction to the lectures and practice which are necessary for the creation of a theoretical chemical and practical analytical foundation, and a more thorough training in the metallurgical branches of instruction depending on physical and chemical principles.

3. More instruction in the technics of machinery and stricter adaptation of this course to the needs of the metallurgist.

He then outlines plans for a four years' course of study, in which the most noteworthy points are as follows:

In the second year iron construction is substituted for wood construction. A course in the science of firing is given, including burning, reduction, production of heat, delivery of heat and its measurement, fuel and its preparation, coking, production of generator gas, firing, chimneys, etc. After the second year a preliminary oral examination is given in physics, inorganic and physical chemistry, mathematics, machinery, mineralogy and geology, mechanics and building construction.

In the third year special attention is to be given to the construction of furnaces and apparatus, and an encyclopædic lecture course on the science of mining is to be given.

The fourth year is necessary for specialization in various branches, such as the working of malleable iron, metallurgic construction, etc., transportation rates, estimates on foundry building, physical metallurgy, practice in translating technical or scientific matter from foreign languages. Chemical analysis is valuable in the training of the iron metallurgist. After testing raw materials and middle and finished products,

he understands better their chemical and physical nature and the connection between the two. The requirements for a diploma are the presentation of a laboratory note book and a certificate of at least one year's practical work, also a theme on some subject of construction or of metallurgy. Candidates are also to be required to pass an oral examination in metallurgy of iron, the science of testing iron, electro-metallurgy, science of machinery, electro-technics and the technology of iron.

Dr. Wüst finds reasons in the position of Aachen why such a fully developed course in iron metallurgy should be given at the University of Aachen. He gives statistics showing the number of blast-furnaces, converters, Martin furnaces, steel works, etc., there are in the neighborhood of Aachen, the amount of hard coal, coke, iron and pig iron produced, and the number of students at the university studying the various branches, the last-named statistics showing a great increase in the number of students in mining and metallurgy. The geographical position of Aachen also gives opportunity for observing and studying the workings of various processes in iron metallurgy and mining. He gives some practical suggestions as to the use of the buildings and the laboratories at Aachen, the arrangement of machinery, apparatus, etc., the number of new professorships and instructors needed, and the increase in appropriation necessary, which would amount to 54,000 marks yearly, with an appropriation of 450,000 marks for reorganization of instruction.

He further gives statistics showing that in 1899 Germany was the third country in the amount of iron produced (in kilograms per capita), and states that the development of the iron industry in Germany demands a fully developed course of instruction in iron metallurgy and engineering. **No. 48. C.**

**The Deformation of Materials.** H. Bouasse. "Bulletin de la Société d'Encouragement pour l'Industrie Nationale," October 31, 1903. 7,500 w. — Among the advances which have been made in the applied science of engineering one of the most interesting is the progress which appears in the treatment of the strength of the materials of construction. Formerly it was considered sufficient if a few experiments were made to ascertain the load which a given material would

bear before rupture took place, and the engineer was held to have done his duty if he proportioned his structure so that the load never exceeded a certain fraction of this breaking-load, this fraction bearing the imposing name of " factor of safety." Some engineers held that a factor of safety of ten was necessary, others, less conservative, were satisfied with lower proportions, but the whole consideration of the matter was empirical and arbitrary, and had no basis in any real knowledge of the true behavior of the material under stress.

With a more scientific study of the manner in which various material resisted the action of stresses a more rational view of the subject began to obtain, and at the present time the whole tendency of the ablest engineers is to get entirely away from empirical formulas and methods and to consider each material by itself according to the actual conditions of use. This point of view has brought into prominence the fact that long before the breaking-load is reached a material suffers molecular changes which render it unfit for further loading to any extent.

The improvements in testing machines and in the apparatus for recording the relation of load to deformation have taught us much concerning the true behavior of materials under stress, and in an article upon the deformation of materials, by M. H. Bouasse, in a recent issue of the " Bulletin de la Société d'Encouragement pour l'Industrie Nationale," this side of the subject is discussed in a very interesting manner.

M. Bouasse emphasizes the necessity of differentiating the work of the engineer in the study of materials from that of the physicist. The latter, in his laboratory, may undertake investigations of a high degree of precision, and the results, wholly accurate and interesting, may yet be of comparatively small value for the purpose of forming the broad generalizations necessary for the framing of laws and formulas for the working engineer.

Taking up the much-discussed question of the limit of elasticity, M. Bouasse examines the case of a wire subjected to a load increasing in proportion to the time, and gives the diagram corresponding to the conditions of stress and strain. He emphasizes the fact that there is no abrupt or sudden change in the curve indicating a precise point at which the

extensions cease to be directly proportional to the loads, the rate of stretch increasing gradually, forming a rounded corner in the diagram. In other words, a pronounced region of inflexion is found on the curve, but not an abrupt angle. At the same time he admits that an approximation to the true limit of elasticity may be deduced from such a record, and considers that such an approximation may safely be used in the practice of machine design. M. Bouasse puts himself on record as affirming that the ultimate breaking-load is of no scientific value whatever, so far as the researches of the physicist are concerned, although it is possible that it may be of some service to the engineer.

The law of Tresca is cited as of especial value to the engineer, this principle being that, with repeated removals and re-applications of the load in the testing machine, the curves drawn will practically coincide so long as the stress is within the elastic limit; practically such curves are straight lines of very slight inclination.

M. Bouasse examines in detail the complex phenomena which accompany the production of deformations in materials, and considers the influence of various methods of producing deformations upon the results. Thus it is quite possible to apply loads in such a manner as to permit altogether erroneous conclusions to be drawn, and unintentional or premeditated deceptions may be produced. A series of tests, alike in all respects with the exception of the speed of application of the load, revealed the influence of the time element, a heavier load being required to produce the same extension in a short time than is necessary when the force is applied more slowly.

When it is understood that a difference of ten per cent or more in the apparent strength of the material may appear from this source alone, the importance of considering the time element is evident. This difference is that due alone to the behavior of the material under rapid test, and is in addition to the error which may be caused by the inertia of the operative parts of the testing machine itself.

The influence of local hardening of the material under test is examined at length by M. Bouasse, and he shows very clearly that any assumptions based on a supposed uniformity of conditions throughout the whole test piece may lead to very misleading results.

So far as actual testing is concerned, the investigations of a material may be made according to three different methods. In the first case the material may be examined in connection with the completed structure of which it forms a part, as, for example, the metal of a tire, in place upon the wheel where it is to be used. In such cases, theoretical considerations are entirely out of place. The important matter is to reproduce, as nearly as possible, the actual conditions under which the object is to be used.

The wheel may be broken under a hydraulic press, but the conditions imposed by the artillery tests are more practical, these consisting in placing the wheel upon a caisson or a gun carriage, and hauling it over several hundred kilometers of broken country.

The second kind of test includes the material before it has reached the final form and position of actual use. In such instances the final destination of the material may even yet be indeterminate. Here the only requirement should be the conformity of the piece under test to certain stated requirements of specifications, or its correspondence to a given standard of comparison. Even here a theory of deformations is inapplicable, and while the results may be of the utmost importance and value in construction, they are altogether unsuitable to be used as the basis of a scientific theory. In the third kind of tests the whole aim should be the procuring of data from which to deduce the theory and the actual laws of deformation. Such testing is the proper work of the physicist, to be performed in the laboratory, entirely apart from the practical considerations which must control actual working tests of the two previous classes. Only by the comparison of a vast number of laboratory tests can the true scientific laws of the deformation of materials be determined, but when thus determined, they will be rational and not empirical laws, capable of practical applications of the highest value. Abstracted in " Engineering Magazine," January, 1903. **No. 49. F.**

**Some Observations on Gas-Reheating and Regenerating Furnaces.** Thomas Stapf. "Stahl und Eisen," December 15, 1903. 9,000 w. — The author, after describing fully the defects of construction and the expense and difficulties in connection

with the operation of the ordinary types of reheating fur-
naces, gives a full and very interesting description of a new
furnace designed by him, a cut of which is shown in Fig. 1.
It is a gas furnace with revolving flame adjustment and is
remarkable for its long hearth, which is divided into two
equal chambers by a middle fire bridge crosswise to the
length of the hearth. The canals bringing gas and air to the
hearth are arranged by measuring or fitting their cross sec-
tion in proportion to the fusing space with such an inclination.
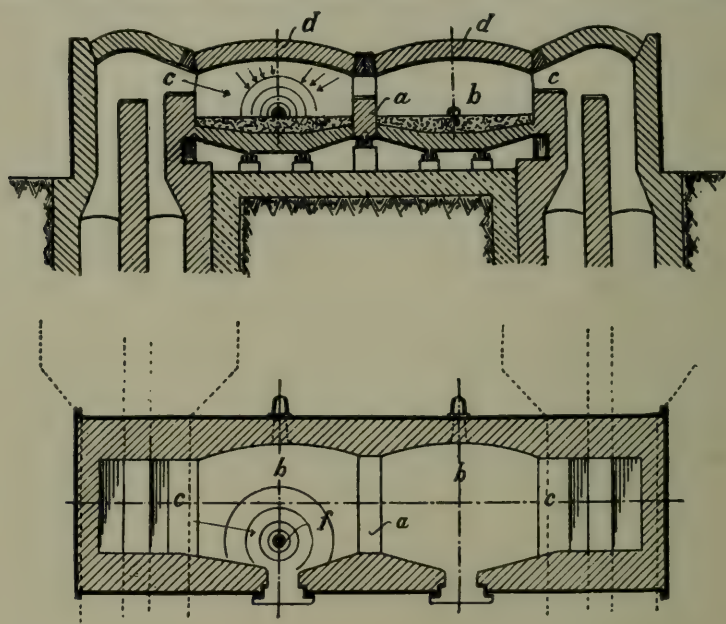


Fig. 1.

towards the sole, and the arch of the furnace is constructed
against the middle fire bridge in such a way that the flame
and the heat rays thrown back from the roof are directed to
a certain place in the chambers behind the working door, so
as to bring and keep the highest temperature there. (The
extent of this hottest zone depends, of course, on the normal
size of the pieces worked.) In working such a furnace, ex-
perience has shown that it is best to divide the charges in
such a furnace into halves in space and working time. The
first half charge is placed on that half of the hearth where

the products of combustion withdraw. After being heated here the flame is reversed, so that this part of the charge comes into contact now with the hotter part of the flame. Then the second half is placed on the other half of the hearth over which the more or less cooled gases from the first half of the hearth extend. The separate pieces in the first charge are turned so as to be heated evenly, and then are taken out to be worked over. After the first piece is taken out, the next warmest is brought to the hottest place in the furnace, and so on until the half charge has been all worked over. Meanwhile the second half charge has been heated strongly on the first half of the hearth, and now by changing the direction of the flame is brought nearer the hottest zone shortly before the last pieces of the first half are taken out. While the second half is being heated to the required temperature and worked out, the first half of a second charge is put in, and so on. There may be one or two openings for the outflow of slag, and each part of the hearth may have one or several doors for working.

In such a furnace as this the gases have an opportunity to cool because of the greater length of the hearth in proportion to its breadth, the per cent of fuel used is much smaller and the working grade therefore higher. The masonry and polished parts of the regenerator suffer less from being overheated, and there is little loss of heat through the chimney. The division of hearth and charge must be made so that the half hearth is smaller than the whole hearth in an ordinary furnace and the half charge is smaller than a whole charge in the old style. The direction of the flame must be so arranged that the separate iron bars cannot reach the required temperature at the same time, but in the order in which they are brought to the hottest zone, and then worked out. After each half charge, the direction of the flame must be changed.

In this process the iron or steel bars are not subjected to the oxidizing gases for any appreciable time. The difference in temperature between the hot gases and the load is much greater, because a much smaller part of the charge is heated at a time. The great advantage of heating the charge in parts is that there is hardly a moment when the contents of the furnace cannot take up more heat, so the difficulty of incom-

plete combustion is overcome. Advantage is taken in this furnace of the "counter current principle." The firing can be so regulated that an immediate and complete combustion of the gases with the secondary air takes place, which brings about a saving in fuel. The gases can pass over the middle fire bridge during the working out of the first half charge, and warm the cooler second half. This is a saving in heat, of course.

With the increase in the efficiency of the furnace comes a decrease in the per cent of wages paid per 100 kg. produced; for only one experienced, well-paid worker is required, though more cheap assistants are needed.

Tables are given showing the economy of this sort of furnace. The amount of fuel required, the waste in slag, the efficiency and working grade of various furnace systems are shown, as well as the thermal events in ordinary gas-reheating furnaces. The three great advantages of the gas-reheating furnace patented by Stapf are as follows:

1. The working grade of such a furnace is higher; that is, the expense in fuel is much less.

2. The average temperature of the charge rises to the highest reheating temperature only at the end of the charge.

3. The time of the charge is much shorter, and so the efficiency of the furnace is much greater than in ordinary furnaces.

Therefore it would seem that the gas-reheating furnace with divided hearth is a step forward in the production of iron and steel manufactures. **No. 50. C.**

**The Elastic Limit of Metals.** Ch. Frémont. "Bulletin de la Société d'Encouragement pour l'Industrie Nationale," September 30, 1903. 10,600 w. — The question as to the real existence of a "yield-point" in the case of materials subjected to a stress has been discussed of late from various standpoints, and in some quarters there has appeared a disposition to dispute the existence of any such stage in the resistance of metals under load. Under these circumstances the recent investigations of M. Ch. Frémont, published in a recent issue of the "Bulletin de la Société d'Encouragement pour l'Industrie Nationale," demand notice and review, showing as they

do the behavior of metals when subjected to deforming stresses.

According to the position taken by Lebasteur, the conception of an elastic limit involves the supposition of the existence of a period during which the deformation is instantaneous, a matter upon which a difference of opinion exists. The physicist, by using the most precise methods of measurement, is able to show that permanent deformations are produced by the lightest stresses, and by the use of suitable recording devices M. Frémont has been able to demonstrate that successive applications of slight stresses are able to produce successive small permanent deformations in the frame of a machine intended to be subjected to much larger operative loads.

It is possible, however, to show that although small stresses will produce permanent deformations, the successive applications of small loads will cause these to become smaller and smaller, until no further appreciable set appears. These phenomena, however interesting to the physicist, may therefore be neglected in studying the strength of materials from the viewpoint of the constructor. The existence of an absolute limit of elasticity is a matter which is contrary to the general experience of mankind, since absolute permanence of any physical structure is hardly conceivable, hence the term should be taken rather as relative to the behavior of the material on either side of such an assumed limit.

According to the French commission for standardizing methods of testing, three definitions of the elastic limit are given. (1) The theoretical limit of elasticity; this being the maximum load per square millimeter of original section which produces no permanent extension. This limit is supposed to be measured by observing the fact that within a quarter of an hour after the removal of the load the test piece returns to its original dimensions within a thousandth part of a millimeter in a length of 200 millimeters. (2) The proportional limit of elasticity; this being the point at which the deformations cease to be sensibly proportional to the loads. This limit is supposed to be determined by measuring the extensions to within a thousandth part of a millimeter for successive loads of one kilogram per square millimeter. (3)

The apparent limit of elasticity, or point of origin of deformation under constant load; this being the load per square millimeter of original section under which the extension continues appreciably without the addition of further stress. This limit corresponds to the drop of beam, or fall of pressure-column in the testing machine. As a matter of fact, it is practically impossible to determine exactly the relation of the proportional limit of elasticity to the theoretical limit. By some observers the proportional limit is placed above the theoretical limit, while by others it is stated to be below. M. Frémont gives a number of curves from records of tests showing how such differences of opinion arise from the different behavior of various specimens under test. As a matter of fact, the records of specimens differ under successive increases of load from those obtained under successive decreases, the action in such instances being similar to the behavior of indicator springs under rising and falling pressure tests.

In view of the diversity of opinion regarding the elastic limit, M. Frémont has undertaken to investigate the real action which takes place within a metal under stress, for the purpose of determining what he calls the true elastic limit. As long ago as 1830, it was assumed that a metal had passed its elastic limit when it had undergone a change of texture. At that early date any such change could be observed only after considerable extension had occurred, but with modern methods and appliances, including the use of the microscope in the examination of highly polished surfaces, it is possible to distinguish structural changes much more precisely.

When a substance is non-homogeneous, but is composed of several constituents, each constituent has its own elastic limit, and even when the substance is chemically homogeneous, there may exist several orders, each having its own elastic limit. In practice it is necessary to determine only the minimum elastic limit, as occurring at the moment of the first apparent deformation.

The microscopic examination of materials which have been subjected to stress reveals the fact that some metals show a sudden change in texture with the attainment of a certain stress, while others alter their structure gradually as

the load is increased. These changes are usually clearly visible if the highly polished surface is examined under a magnifying power of about 50 diameters, and when the sudden change appears the whole surface assumes a granular texture, while for those materials which yield gradually the alteration appears in isolated areas, these gradually merging into each other.

It is well known that when a metal is hammered, rolled or otherwise subjected to local stresses which exceed the elastic limit, the portions become locally hardened, and this fact has led M. Frémont to consider the effect of partial and localized stresses upon pieces under test. Experience has demonstrated that when a metal is subjected to stress in a testing machine the first deformations are local, and it is this irregular distribution of strain which renders it so difficult to maintain the stress in the exact axis of the test piece, either under tension or compression, there being a constant tendency of the line of stress to shift with the shifting resistance. In order to localize the stresses, so that the true elastic limit may be determined by microscopic observation, M. Frémont recommends the use of a test piece of diminishing cross section, with the object of localizing the maximum stress within a limited area in which the microscopic observations may be made. Numerous photographs of tests upon such pieces, showing the extent to which the effects may thus be concentrated, are given, under flexure as well as under tension and compression. The whole subject is one which demands fuller examination and discussion than can here be given, but the general conclusions are as follows:

The theoretical elastic limit is the average load per unit of section under which the true elastic limit is attained at a definite point of the piece under test. Its value depends, not only upon the given limitations of elongation and of contraction of section, but also upon the adjustment of the test piece and the precision with which the test is made. It is not the elastic limit of the metal, but only the elastic limit of the special piece under the particular conditions of the test.

The relation of the proportional limit to the theoretical limit of elasticity is, as has already been said, very indefinite. Its value depends to a great degree upon the local defor-

mations, and in cases in which both tension and compression occur, one may counteract the effect of the other.

The apparent limit of elasticity, the so-called "yield-point," is the average load per unit of section at which the true elastic limit is reached in all parts of the metal. It approaches more closely to the true elastic limit than does the theoretical limit, but it must not be confounded with it, since the stress is not uniformly distributed over the whole section, owing to the local hardening which takes place under the localization of strains. It is only when the conditions of the test are such that the stress is closely localized, so that marked local hardening can not occur, that the theoretical and the apparent limits of elasticity agree closely with the true elastic limit.

M. Frémont affirms that there is but one elastic limit for a given metal, the one which he calls the true elastic limit, and this can be determined only by observation, under proper conditions, of the effects of stress in producing strain in the material; such a limit alone having the characteristics of a physical constant. The various elastic limits which it is customary to employ may involve very serious errors, and they should be subordinated to the production and study of discontinuous deformations, which continually occur in practice, under conditions which it is impossible to predict. Abstracted in "Engineering Magazine," December, 1903. No. 51. F.

**A Compact Gas Engine, Beam Type.** C. H. Morgan. Paper read at the December, 1903, meeting of the American Society of Mechanical Engineers. — The paper describes a recently developed engine especially designed to utilize blast-furnace gas as fuel.

Discussion brought up the error in the common belief that the impulse upon the piston of an internal combustion engine is in effect a blow of more or less severe character. Professor Reeve urged that a blow necessarily involves velocity, of which there is none possible in the case of gas at point and time of ignition in a combustion engine. The explosion is a process of combustion, requiring time for its accomplishment and probably generally approaching the conditions of

impact much less nearly than is the case in the steam engine, where the steam is admitted at high velocity, striking upon the piston a blow whose effect is well known as affecting steam engine maintenance. As a matter of fact, the combustion engine gives a very uniform crank effort. B. F. Thwaite, of England, was invited to speak of his experience with blast-furnace gas engines. He emphasized the fact that it is wrong to regard the gas engine as an explosion engine, since the burning of the charge is progressive and not instantaneous. Speaking of the reputed "leanness" of blast-furnace gas, he called attention to the dilution of the richer gases with larger proportions of air in gas engines, thus bringing them to an equally "lean" condition in actual use. That blast-furnace gases have given trouble in engines he attributed entirely to the presence of dust and not at all to lowness of calorific value. He stated that he has now entirely obviated even this difficulty, by means of his cleaning apparatus, illustrated and described in "The Iron Age" for last week. Regarding the suggested use of gas-engine exhaust in heating the blast stoves, Mr. Thwaite called attention to the fact that the exhaust gases are not above about 500° in temperature. Halving this amount shows little usefulness for blast heating. Mr. Thwaite stated that the best thermal results are to be obtained for piston speeds of about 800 to 900 feet per minute; that blast-furnace gas is ideal for power purposes and that the present wastes of this power are of extreme value.

Mr. Uehling: There is no question before the mechanics, and especially the iron manufacturers, of this country of greater importance than that of the utilization of blast-furnace gases. Some time ago I took the pains to determine, as nearly as might be, the power that is wasted in the manufacture of iron. I found that there were in excess of 1,750,000 horse power going to waste with the rate of manufacture as it was about a year ago. And since then I have had the opportunity of investigating the cases of several plants and I find that my figures are too low. I found that there was available for outside purposes, over and above the requirements of the blast-furnace itself and the heating of the blast stoves, 800 horse power per ton of iron, produced per hour. There is one plant, for instance, where there are four blast-

furnaces and large works besides, where they would require about 20,000 horse power for blast-furnaces and all, and they would have, after supplying all the power required to run their works, about 18,000 horse power for sale. The plants do not all come out the same, because it depends on the character of the iron they make and the fuel and the character of ore that they have to reduce; but the power available is in no case less than 800 horse power per ton of iron manufactured per hour. There seems to have been, especially in this country, great hesitancy in receiving this idea of utilizing blast-furnace gases, and on the first casual glance it seems as though there could not be much of it, because the gas is very clean; but, as already stated, it is an ideal gas for internal-combustion engines, and when you come to figure it out it does not differ very much in composition of the explosive mixture in the engine from a very strong gas, because with illuminating gas you have to add from six to ten times — I think about eight or nine times — the quantity of air to make the explosive mixture. Now, in blast-furnace gas 0.7 of the volume is all that is theoretically required, and you add about one to one, I think. [Mr. Thwaite: That is right; one to one.] Now in your blast-furnace gas you have 25 per cent combustible, and in your illuminating gas we may assume you have 100; but you add air, which is nearly 80 per cent nitrogen. Besides, the elements which are in the illuminating gas do not lend themselves to the high compression and you are liable to get premature explosions; whereas the elements in the blast-furnace gas not only lend themselves to compression, but it is necessary that they should be compressed in order to get the explosion with certainty, due to the large excess of carbon dioxide, which is a great retarder of combustion. "The Iron Age," December 10, 1903. **No. 52.**

**Blast-Furnaces with Continuous Flow of Metal.** A. Sattmann. "Stahl und Eisen," November 1, 1903. 2,200 w. — We published in the issue of "The Iron Age," November 12, an article describing a blast-furnace, with continuous flow of metal, the facts being taken from "Stahl und Eisen." * A

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* See *Iron and Steel Metallurgist*, January, 1904. Abstract No. 1.

later number of our German contemporary contains an interesting letter on the subject from Alexander Sattmann, who agrees that a successful " continuous " furnace would have many advantages over those working on the present system.

He points out that the essential novelty in Stapf's invention is the construction of a dam or retaining wall in front of the tap hole, causing the molten metal to rise above the latter and thus prevent the egress of the cinders therefrom. The arrangement shown in Fig. 4,* " The Iron Age," November 12, he characterizes as an unsuccessful adaptation of an invention of his own. The success of Stapf's arrangement would depend on the hearth bottom always remaining at the same height, which in practice is not the case. If the general level of the furnace bottom should not rise, it would contract the area of the iron notch and necessitate raising the same which, under the circumstances, would be a difficult operation. Even if the bottom level should remain unchanged the washing action of molten iron on both sides would soon destroy the upper part of the iron-notch and entail difficult repairs.

Mr. Sattmann refers to a previously published suggestion of his own — namely, to effect the separation of the metal and slag in a slag separator, connected with but separate from the furnace proper. The iron runs from the usual iron-notch into the fore chamber of the separator, thence under a dividing wall which restrains the slag, into the second chamber and from there to the pig bed or casting machine. The slag-notch may be either in the fore chamber of the separator or in its usual place in the hearth. In the latter case it is necessary to dam up the metal to a higher level than in the former. If the cinder-notch is in the separator, slag and iron flow together through the iron-notch without filling the same, but if it is in the hearth the iron-notch will be permanently subject to the liquid pressure of the bath of metal. By permitting iron and slag to run out together continuously as fast as made the metal will be subjected for a shorter period to the influence of the incandescent coke, and will, in consequence, contain less carbon. The opinion is now very generally held that carbon enters the

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* See *Iron and Steel Metallurgist*, January, 1904. Abstract No. 1.

iron after the latter has descended below the tuyère level, the absorption being accompanied by considerable loss of heat. If this view is correct it is plain that the continuous process would yield a metal hotter and lower in carbon than is now the case, which would be clear gain to the steel works, especially if using direct metal.

The accompanying figures show the construction of the slag separator. The slag runs off through a clay-lined pipe (omitted in the figures) which bends down into a sump. The height from the bottom of the pipe to the overflow of the
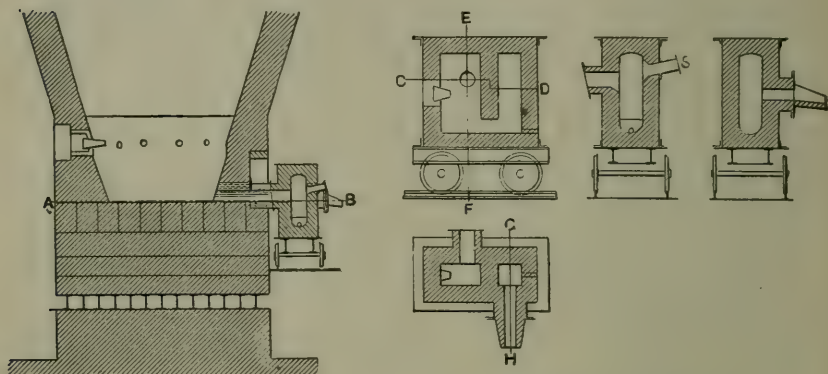


The Sattmann Slag-Separator
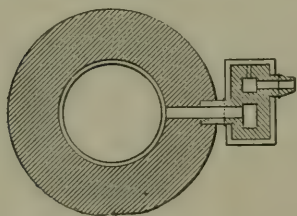
sump must correspond to the pressure in the furnace. If the cinder-notch is to be located in the hearth the opening through which the iron leaves the separator must be correspondingly higher up, necessitating the chambers being built higher than is the case in the figures, which presuppose the slag as well as the metal entering the separator. At the floor level of the apparatus is a tap hole for completely emptying the same in case of need. Opposite the opening from the furnace is a " peep-hole " for observation, and through which a bar can be used if necessary. It will obviously be a matter of greater difficulty to keep this opening clean if the slag is run off from the hearth than will be the case if the cinder-notch is in the separator. To facilitate rapid changing it is convenient

to have the whole arrangement on a truck, and to so arrange the short section of track on which it stands when in actual use that it may be raised or lowered hydraulically or otherwise. This will permit of rapid adjustment to slight variations in the position of the iron-notch.

Mr. Sattmann sums up the advantages which his apparatus has, as compared with Mr. Stapf's invention, as follows:

1. The iron-notch is easily accessible.

2. The separator can accommodate itself to the height of the iron-notch.

3. The refractory block which actually separates the slag can be changed in a few minutes.

4. No part of the hearth jacket is subject to the action of molten metal on both sides at the same time.

5. The separator can be attached to any furnace without necessitating a shut down of more than a few hours.

6. The apparatus is quite inexpensive.

7. In case of need the former system can be reverted to in a few hours. "The Iron Age," December 10, 1903. **No. 53. C.**

**Specifications for Steel Castings, Boiler Plates, etc.** New York meeting of the American Society of Mechanical Engineers, December, 1903. — The committee on specifications for boiler plate, rivet steel, steel castings and steel forgings was represented by Professor Spangler, who gave practically a report of progress. In accordance with his suggestion the report, after some discussion, was referred for further consideration to Committee No. 1 of the American Society for Testing Materials. Professor Spangler pointed out what he considered the narrow limits of the field under survey. There was some difference between steel of from 40,000 to 85,000 pounds tensile strength, such as was covered by the specifications, and other steel. Commenting further upon some of the criticisms already advanced he was of the opinion that when the physical and chemical requirements were met the steel would have two-thirds of the ultimate strength.

Wm. Kent submitted a translation of the metric measurements of the standard test pieces to English units. W. W. Dingee offered the rivet specifications of the J. I. Chase

Threshing Machine Co., of Racine, Wis., for the favorable action of the committee.

Professor R. C. Carpenter was in favor of the retention of the yield-point determination. He believed that it would lead to more care by manufacturers and more accurate results would come from that care. An extended survey of the report was given by Gus C. Henning. He found the specifications not only ambiguous in very important details but a number of them positively impracticable. He presented a spirited argument in favor of retaining the determination of the yield-point as involving no complicated routine in actual practice and at the same time as giving data of the highest importance to engineers. His discussion of the specifications was thorough and to be well understood would require to be accompanied by the temporary report of the committee. "The Iron Trade Review," December 10, 1903. No. 54.

**Nickel-Steel Locomotive Tires.** " Railway Machinery," November, 1903. 1,100 w. — Under ordinary working conditions the machinery of a locomotive will not require overhauling so soon as the tires will require re-turning, say roughly, once for each 50,000 to 75,000 miles, depending on the service, grades, size of drivers, etc. With good water and good care of the running gear the tires may be turned two or three times before extensive boiler and machinery repairs become necessary. During these periods of tire-turning the locomotive is necessarily out of commission for a number of days, which during the height of freight movement is often a serious matter. The result is that often a locomotive is run with bad tires, to the great detriment of the track. Some roads have adopted the plan of removing worn tires in the roundhouse, using gasoline heaters, and replacing them with tires that have been turned. The worn tires, mounted on extra wheel centres or held in chucks, are turned as a matter of regular shop routine to replace another set, when required. But, while this is a step in advance, it does not realize the desirable condition. If we could get locomotive tires made of a steel that would give a mileage equal to that of the boiler and ma-

chinery between overhaulings, and which would permit the
tires to be safely worn down at least one-half inch more than
now possible, it would considerably increase the number of
engines that the average repair shop could take care of, to say
nothing of the increased annual earning capacity of the motive
power.

In accordance with its accepted policy that nothing is too
good or too costly to be used, provided its use shall show an
increase of efficiency sufficient to show a profit, the Pennsyl-
vania Railroad is going to try the experiment of using nickel-
steel tires, having already placed an order for same. It is
generally known that this road is already using nickel-steel
rails on some of its curves where the traffic is very heavy,
notably the Horseshoe Curve above Altoona, Pa. From pres-
ent indications it is thought that the nickel-steel rails will
wear three or four times as long as the ordinary steel rails.
Of course, there will be no such difference in the tires, but
there should be a considerable increase of mileage between
turnings. **No. 55. A.**

**Carbon in Iron.** " The Ironmonger," December 5, 1903. —
On November 27 Professor Turner lectured before the mem-
bers of the Metallurgical Society of the Technical School at
Birmingham on " Carbon in Iron," with special reference to
foundry practice. The lecturer mentioned at the outset that
the difference between cast iron, wrought iron, and steel was
due primarily to variations in the percentage of carbon. That
pure carbon could combine with pure iron, without any inter-
mediate action, had long been experimentally proved by Rob-
erts-Austin; while Saniter had shown that under ordinary con-
ditions the maximum amount of carbon which could be pres-
ent in cast iron was about 4.25 per cent. The amount of carbon
dissolved was, however, dependent upon the temperature, and
also upon the proportion of manganese or chromium, which
increase, or of silicon and aluminium, which decrease, the
solubility of carbon in iron. Carbon was formerly regarded
as occurring in two forms, called respectively " combined "
and " graphitic "; but Ledebur showed, about ten years ago,
that carbon exists in iron in at least four forms, combined car-

bon being made up of two varieties, one known as " hardening " and the other as " carbide carbon "; while the graphitic form may be divided into " graphite " and " temper," or annealing carbon. The lecturer pointed out that the physical properties of cast iron, including softness, soundness, toughness, and other characteristics, were largely dependent not only upon the amount of graphitic carbon which was present, but also on the form in which that graphite occurred. Hitherto no dividing line has been recognized between graphite and temper carbon, but recent researches conducted in the University of Birmingham had shown that graphitic carbon might be classified into various kinds, according to its size and other characteristics. Professor Turner stated that promising results had already been obtained by taking graphite carbon obtained from the action of acids upon cast iron and classifying it by means of fine sieves, the result being that different proportions of intermediate and fine graphite were obtained from different grades of pig iron. In a similar way, by means of microscopic observations it was possible from a study of the graphite to determine the strength and suitability of castings for any required purpose. A large number of slides were shown illustrating the characteristic appearance of various kinds of cast iron, and from a photograph prepared from specially strong cast iron made in his series of silicon experiments in 1885 the lecturer indicated the special and characteristic microscopic appearance of iron possessing unusually good mechanical properties. It was believed that microscopical and mechanical examination on the lines indicated would enable the iron-founder definitely to determine the character of his material and to avoid many difficulties with which he has hitherto been troubled. **No. 56.**

**Alteration of Fire Brick by Blast-Furnace Gas.** Frank Firmstone. " Iron Trade Review," December 24, 1903. 1,950 w. Read at the New York meeting of the American Institute of Mining Engineers. — The author describes the complete disappearance of a part of the back lining of a blast-furnace after a short campaign. The destructive action of blast-furnace gases on the lining-brick has often been noticed, and a number of papers have appeared on the subject since

1875; several of late years in " Stahl und Eisen." One case, occurring at a furnace in the Cleveland district in 1875, was very thoroughly investigated by Mr. John Pattinson, of Newcastle-upon-Tyne, and the results were published in " Journal Iron and Steel Institute " No. 1, 1876, p. 85. Another at Friederich-Wilhelmshütte, Mülheim a. d. Ruhr, was published by Limbor in " Wochenschrift der Ver. deut. Ingen.," 1878, p. 259, and more fully, including a discussion of Pattinson's results, in " Bull. de l'Industrie Minérale," 2d series, tome X (1881), p. 483. In both of these cases the brick in an intermediate zone of the furnace were disintegrated by carbon deposition, brought about by the action of carbonic oxide on the spots of iron oxide in the brick, in accordance with the well-known action between carbonic oxide, iron oxide and metallic iron at certain temperatures; while lower down, the bricks were largely impregnated with alkaline salts. In the case the author now reports, he has no doubt that the same action destroyed the brick in the upper part of the furnace, but positive evidence is lacking because of the total disapparance of the bricks a little above the place from which the piece analyzed was taken. In confirmation of this opinion it was noticed that the cast-iron hopper had been much attacked by the gas, and presented, in places, considerable cavities filled with carbon and particles of disintegrated cast iron. There were also considerable deposits of carbon in several places where two castings had touched without making a gas-tight joint. **No. 57. A.**

**American Tests of Rapid-Cutting Tool Steels.** " The Iron Age," December 31, 1903. 3,500 w. — The recent report of Dr. J. T. Nicholson* on experiments with rapid-cutting tool steels, as given by abstract in " The Iron Age " for November 26, page 28, has afforded much valuable data and information on this very important and highly interesting subject. The Lodge and Shipley Machine Tool Company, Cincinnati, Ohio, were among the first to adopt the Taylor-White process of treating steels for high-speed cutting tools, and have followed it up by trying nearly every other high-speed steel as offered.

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* See *Iron and Steel Metallurgist*, January, 1904. Abstract No. 2.

Frequently quite an improvement would be noted and a quantity purchased, only to find something later apparently much better. The subject thereby became very complex.

High-speed steels are now so numerous that it has become necessary to select one of them if possible for universal use, and thereby cut down the great variety now scattered about the shops, preventing maintenance of the maximum speeds for all tools, as no standard speeds can be definitely fixed and successfully maintained under such conditions. While testing one of their high-speed lathes, which has been designed to meet the new conditions and requirements brought about by these new steels, the Lodge and Shipley Company have conducted several series of experiments to determine the relative values of the several high speed steels, the speed limits which it is possible to maintain, and the relative breaking-down point of each grade of steel tested.

For tools were selected seven brands of the well-known high-speed steels, and several tools of each steel were made, all of the same size, shape, and angles.

Summing up the results of these tests, it would appear that with one of the brands of steel, tested and oil hardened, it is feasible to maintain much higher speeds than the deductions from Dr. Nicholson's experiments would imply, and in many cases these conclusions are being lived up to in the everyday shop practice of the Lodge and Shipley Machine Tool Company. **No. 58. A.**

**Mond Gas-Driven Rolling Mills and Power Plant at the Works of Messrs. Monks, Hall & Company, Ltd., Warrington, England.** "Iron and Coal Trades Review," November 27, 1903. 3,500 w. — A fully illustrated description of rolling mills driven by a gas engine using producer gas manufactured in a Mond Producer. The plant includes two producers, having each a capacity of 2,000 horse power. The consumption of coal is approximately one ton for each 100 horse power per day. Slack is employed, and it is calculated that one ton of slack produces about 145,000 to 150,000 cubic feet of gas, of which the calorific value at the time of our visit was 140 B. T. U. per cubic foot. It follows that about 2,900,000 cubic feet of gas are made per day. Assuming that 2,000 horse

power are continuously generated, this gives a consumption of a little over 60 cubic feet of Mond gas per horse-power hour. The analysis of the gas is as follows:

|  | Per Cent. |
|---|---|
| Carbonic acid | 12.6 |
| Carbonic Monoxide | 14.6 |
| Hydrogen | 25.6 |
| Marsh gas | 3.6 |
| Nitrogen | 43.8 |

The rolling mills plant includes two 15-ton heating furnaces, heated by Mond gas, a 16-inch cogging and a 10-inch finishing train. The finishing train has four stands of rolls, and the cogging mill, one; both cogging and finishing mills are driven by a 600-horse-power Premier engine. The driving of rolling mills even of this size by a gas engine is an innovation, for at the time the matter was decided on by Mr. Monks there were certainly no rolling mills in existence driven by gas engines. The plant is said to run very satisfactorily. The works close at the week's end, the producer being banked and the gas plant shut down on Saturday and started up again on the Monday morning, when a satisfactory quality of gas is obtained in about 15 minutes. **No. 59. B.**

**Steel-Hardening Apparatus.** G. L. F. "Zeitschrift für Werkzeugmaschinen und Werkzeuge," June 5, 1903 — After a number of trials and experiments, Louis Bahner, of Berlin, has brought out an apparatus for hardening steel that is said to overcome the well-known troubles and difficulties surrounding that class of work. The treatment depends upon the fact that the object is to subject the whole piece to a continuous stream of water forced into a tank, in such a way that an equal and uniform hardening is obtained. As the result of the contact of the red hot piece of metal with the surrounding liquid, it is well known that a steam envelope is formed about the former, which prevents the access of the water to the hot surface and thus checks the hardening process. Even by moving the piece about in the water this difficulty is not altogether obviated; for, if a closer contact of the hardening liquid is obtained

on the side toward which the piece is moving, there is still the existing steam pressure on the other side.

The illustration shows one form of the apparatus referred to, as designed for large pieces. The water is delivered through the pipe *A* and enters the inner cylinder at four points opposite where the piece to be hardened should be placed, and
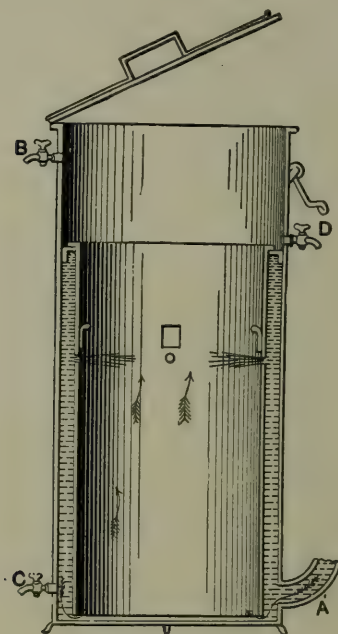


Hardening Tank

flows out at *B*. In smaller designs the water is admitted at the bottom only. The object is to cause a current of water of uniform temperature to flow evenly over all of the surfaces of the submerged piece and thus produce a constant rate of cooling at all points. " Railway Machinery," November, 1903. **No. 60.**

**Mild Steels as Employed in the Construction of Electric Machines.** G. Charpy. " Éclairage Éléctrique," October 31, 1903. 4,760 w. — The author has investigated the mild steels as used in the construction of electric machines, the first point

considered being their electric resistivity. The results obtained by C. Benedicks, viz., that a dissolved atom of a body, expressed by its " value in carbon," will augment the resistivity by constant quantities, viz., 59 microhm cm., are borne out by Barrett, Brown, and Hadfield's experiments. As regards the permeability, the highest value found by the author in the course of measurements made by means of a Picou permeameter on square bars of silicon and aluminium steels, containing 2.5 per cent of either of these metals is 2,260, corresponding with an induction of 6,000 C. G. S. In order to confirm indirectly a hypothesis according to which hammering the steel would result in breaking and deforming the constituent grains, thus augmenting the hysteresis, the author has adopted an artificial system by which the structure of hammered steel is roughly represented by soldering together a bundle of mild iron wire, two mm. in diameter, and cutting more or less inclined sections out of this bundle. The author thinks the conditions to be obtained are a high purity and great accuracy and regularity in softening, the only point to be improved being the regularity. Mr. Charpy thinks, however, the silicon and aluminium steels present great possibilities of further improvement on account of their great permeability and low hysteresis. " Feilden's Magazine," December, 1903. **No. 61. C.**

**The Westinghouse Blowing Engine.** " The Iron Age," December 3, 1903. 5,000 w. — The Westinghouse Machine Company of Pittsburg have recently built six blowing engines of the long cross-head type, three of which have been installed in the plant of the Toledo Furnace Company at Toledo, Ohio, and three at the plant of the South Chicago Furnace Company at South Chicago, Ill., all under the general direction of Julian Kennedy of Pittsburgh, consulting engineer for the two companies.

These two plants are practically duplicates, each consisting of three engines ranged in line, the intermediate unit being designed to run as a low-pressure engine in conjunction with either of the other two, which operate on high-pressure steam, compounding being effected through a receiver in the exhaust system of the high-pressure engines. The low-pressure unit
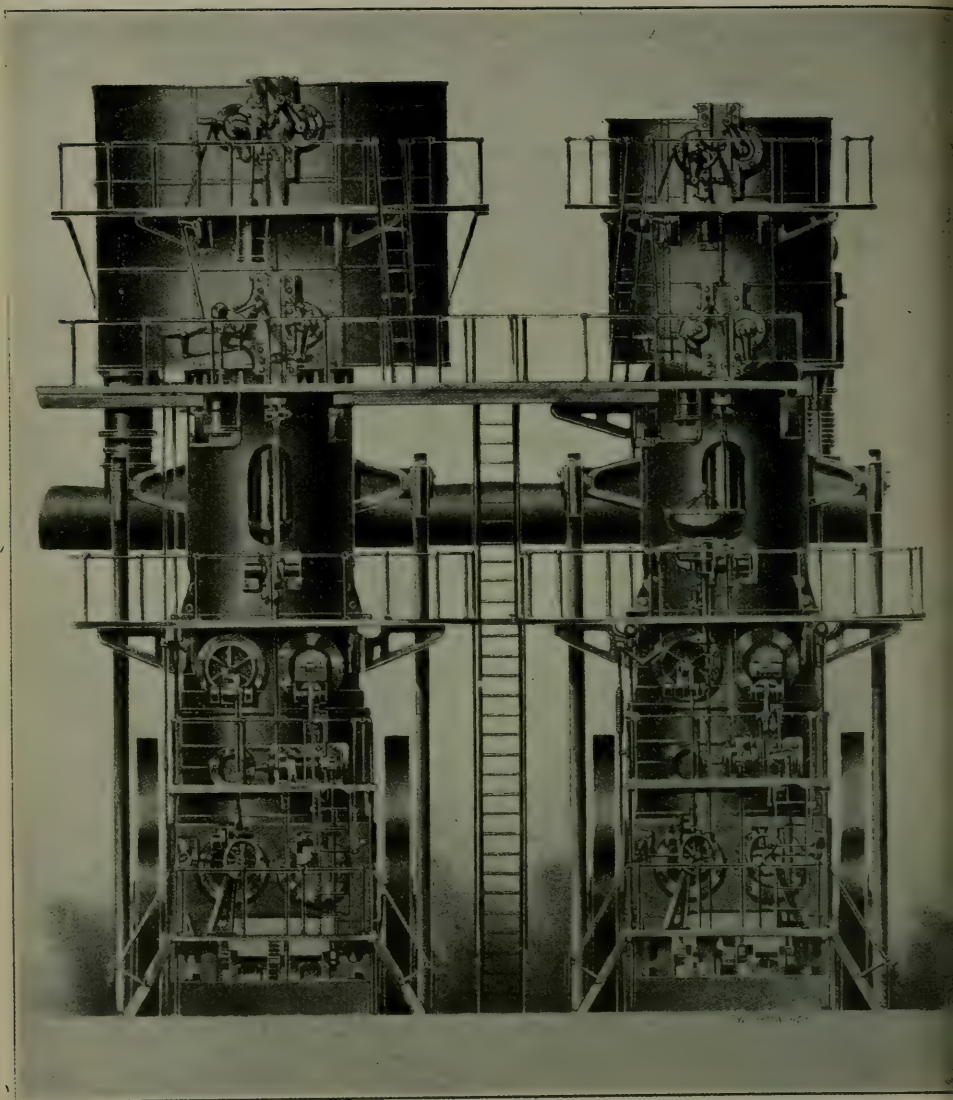
The Westinghouse Blowing Engine.

is also arranged to run on high-pressure steam through a reducing valve. These three engines, each of a capacity equal to 2,000 horse power, are designed to run in couples, either condensing or non-condensing, two being sufficient to supply

the requirements of the operation of the furnaces, one being held as a spare.

The steam cylinders of the high-pressure engines are 50 inches in diameter, and of the low-pressure 96 inches in diameter, and all have a stroke of 66 inches. The air cylinders of all the engines are 96 inches in diameter. The air is delivered into a main duct leading to the furnaces, each inlet provided with a check valve. Regulation is effected through a fly-ball governor, the engine operating at a constant speed, but increasing the air pressure as resistance is offered by the burden in the furnace, and vice versa. **No. 62. A.**

**Nickel-Steel.** " Page's Magazine," November, 1903. — Several important railway companies in the United States are now experimenting with nickel-steel rails. Among these the New York Central and Hudson River Railroad has obtained from the Carnegie Steel Company 204 tons of nickel-steel rails, with the idea of laying them for experimental purposes on the West Albany Hill, where there is a steep grade and heavy traffic. These rails were rolled during June under the inspection of Dr. P. H. Dudley, and are now being laid. The chemical composition of the rails was found to be as follows:

|  | Per Cent. |
|---|---|
| Carbon | 0.418 |
| Silicon | 1.02 |
| Manganese | 0.79 |
| Nickel | 3.38 |
| Phosphorus | 0.094 |

Nickel-steel is to be used for most of the tension members and pins of the great cantilever bridge now being constructed at Blackwell's Island, New York City. This bridge will have one span of 1,182 feet, another of 984 feet, and a third of 630 feet, in addition to two side spans of 469½ feet and 459 feet each, respectively. The nickel-steel used is to contain 3½ per cent of nickel. **No. 63.**

**Iron and Hydrogen.** Dr. H. Wedding and Dr. F. Fischer. " Stahl und Eisen," November 15, 1903. 9,300 w. — The authors describe in detail the results of their researches and

those of other investigators on the effect of hydrogen on various metals, with especial reference to iron. The theory is adopted that hydrogen unites with other substances to form a metallic alloy in a manner similar to carbon, though it may be mechanically enclosed as a gas or held to the iron by surface absorption, just as air clings to the surface of rough bodies. The influence of hydrogen on the properties of iron depends on the form in which it exists. In the metallic form it imparts to iron greater brittleness, and as enclosed gas it acts to form bubbles, the latter being the most disadvantageous.

The amount of hydrogen absorbed depends on the chemical composition of the iron. A high percentage of silicon prevents its liberation, and a high percentage of carbon prevents to a degree the absorption, while manganese, nickel and cobalt aids it. **No. 64. C.**

**Plant of Clearfield Steel and Iron Co.** " The Iron Trade Review," December 24, 1903. 1,100 w. An illustrated description of the plant of the Clearfield Steel and Iron Co. of Pittsburg, at Hyde City, Pa. — These works, which were recently completed and put in operation, include a modern rolling mill for re-rolling standard section rails into light rails. Iron and steel skelp iron, sheet and tin-plate bars, general merchant iron and bars, are also manufactured. The puddle department is equipped with 12 single and four double puddling furnaces. The 18-inch rail mill is of special design, and consists of two stands of three-high rolls and an additional stand of bullhead rolls. The furnace is of the continuous type, and the pusher is operated by a hydraulic pressure pump and accumulator. The furnace is wide enough to take in rails 15 feet long, with a capacity for heating of ten tons per hour of standard section rails. **No. 65. A.**

**Cast Iron Sulphur Standards.** W. B. Ireland. " Iron Trade Review," December 3, 1903. 900 w. — The author contends that if cast iron and steel drilling standards be annealed before analyzing, the volumetric method for the determination of sulphur will give results very close to that obtained by gravimetric methods, while, if this precaution be not taken, it

is well known that the volumetric method generally yields too low results. The author applied this treatment to standard " B " of the American Foundrymen's Association, which is said to yield by the evolution method 0.038 per cent of sulphur, and by the gravimetric conditions method 0.056 per cent. The author's results were as follows:

Without annealing................0.038 per cent S.
                              0.036 per cent S.
After annealing 15 minutes........0.057 per cent S.
                              0.059 per cent S.

To anneal the standard, the drillings are heated for 15 minutes in a covered porcelain crucible. **No. 66. A.**

**Alloys Used for Steel Making.** Dr. J. Ohly. " Mines and Minerals," October and December, 1903. 5,600 w. — The author makes a concise statement of the composition and effect upon the properties of steel of various alloys used in improving carbon steel. These alloys he divides into two general classes, (1) those which have the property of forming with the steel, compounds possessing superior properties in comparison with those of the steel itself, thereby improving the whole mass, while they eliminate simultaneously occluded gases like nitrogen and oxygen, and (2), those which act as reducing agents and remove oxides formed during the process of melting. Among the first group described by the author are, 1, ferronickel; 2, ferrochrome; 3, ferrocobalt; 4, ferrochrome nickel; 5, ferrotungsten nickel; 6, ferrotungsten; 7, ferrophosphorus; 8, ferromolybdenum; 9, molybdenum nickel; 10, ferrotitanium; 11, ferrovanadium; 12, ferroboron; 13, ferromanganese; 14, ferrouranium; and among the second, 15, ferroaluminium; 16, ferrosodium; 17, ferrosilicon; 18, copper silicon. **No. 67. Each B.**

**The Blast Furnaces at Cette, France.** Marre. " La Revue Technique," October 25, 1903. 5,000 w. — An illustrated description of the new plant of the Creusot Works on the Mediterranean. The plant will include six blast-furnaces, one of them being in operation at the present time. The works comprise a briquetting plant, a battery of coke ovens, and the usual blast-heating and other blast-furnace accessories. The

furnace is 23 meters (75.46 feet) high, its diameter at the top is 4.668 meters (15.3 feet), at the foot 5.87 meters (19.3 feet), and at the crucible 3.5 meters (11.5 feet). Its production is 200 to 250 tons per 24 hours. The blast-furnace gases are very carefully purified, and their utilization in gas engines is intended; two gas-blowing engines of 600 horse power each being in course of construction. "Mines and Minerals," December, 1903. **No. 68. C.**

**Manganese Steel.** "Comptes Rendus de l'Académie des Sciences," September 21, 1903. 1,000 w. — L. Guillet reports that micrographic examination of manganese steels shows their close similarity to nickel-steels. Only about one-half the quantity of manganese is required, however, to produce the same effect as nickel. Pearlite steels show great breaking stress and also high resistance to blows. Manganese alone does not render the steel brittle; this happens only when the percentage of carbon and manganese is sufficient to give a martensite structure. Low carbon steels, containing less than 4 or 5 per cent manganese, are not at all brittle. "Engineering and Mining Journal," December 5, 1903. **No. 69. C.**

**Theory of Nickel-Steel.** Ch. Ed. Guillaume. "Revue Générale des Sciences," July 15 and 30, 1903. 17,600 w. — An exhaustive description of the peculiar properties of alloys of iron and nickel and of the theories advanced to explain them. **No. 70. Each C.**

**Notes on the Theory of Nickel-Steel.** L. Dumas. "Revue Générale des Sciences," August 15, 1903. 3,000 w. — An able discussion of the theory and properties of alloys of iron and nickel. **No. 71. C.**

**Contribution to the Theory of Nickel-Steel.** F. Osmond. "Revue Générale des Sciences," August 30, 1903. 3,700 w. — An important and able discussion of the mechanism suggested by Mr. Guillaume and others to explain the properties of nickel-steel. **No. 72. C.**

**Vanadium in Metallurgy; Its Action Upon Iron and Steel.** Marsollan. "La Revue Technique," September 25 and Oc-

tober, 10, 1903. 4,000 w. — A review of the occurrence of vanadium in nature and of tests made by various investigators to ascertain its influence on the properties of iron and steel when added to the latter in small quantities. The second part of the article deals with the influence of vanadium on nickel-steel. "Mines and Minerals," December, 1903. **No. 73.**

**Influence of the Shape and Method of Manufacture on the Strength of Cast-Iron Test Bars.** P. Reusch. "Stahl und Eisen," November 1, 1903. Ill. 2,500 w. **No. 74. C.**

**Putilov's Iron Works at St. Petersburg.** Adrian Byström. "Stahl und Eisen," November 1, 1903. Ill. 3,400 w. **No. 75. C.**

**New Methods for Preventing Piping in Steel Ingots.** J. Riemer. "Stahl und Eisen," November 1, 1903. — This article, which has been reviewed in "The Iron and Steel Metallurgist," January, 1903 (abstract No. 12), has been translated in full, with illustrations, in the "Iron and Coal Trades Review," December 18, 1903. **No. 76. B.**

**Pipe Foundry of the Massillon Iron and Steel Company, Massillon, Ohio.** "The Foundry," November, 1903. Ill. 1,500 w. **No. 77. A.**

**Crucible Cast Steel and Tool Steel.** R. H. Probert. "The Engineer," Chicago, November 2 and December 1, 1903. 6,300 w. — A description of the manufacture of crucible steel and of cemented steel. The annealing, hardening and tempering of steel is also dealt with. **No. 78. Each A.**

**Aluminothermy (L'Aluminothermie).** Camille Matignon. "Revue Générale des Sciences," November 15, 1903. Ill. 14,400 w. — An excellent description of the present condition of this interesting and recent chapter of the metallurgical art. Deals with the application of aluminium to the preparation of metals and alloys, to the welding of tubes and rails, the forging of iron, the casting of steel, etc. **No. 79. C.**

**Analysis of High Speed Steels.** " Iron and Steel Trades Journal," November 20, 1903. 1,800 w. **No. 80. B.**

**Kyellin's Electric Furnace at Gysinge, Sweden, for the Manufacture of Steel.** Frank C. Perkins. " Electrochemical Industry," December, 1903. Ill. 1,550 w. **No. 81. B.**

**West Allis Foundry of the Allis-Chalmers Company, Milwaukee, Wis.** " The Foundry," December, 1903. Ill. 2,300 w. **No. 82. A.**

**Mistaken Blaming of the Steel.** E. R. Markham. " American Machinist," December 3, 1903. 1,500 w. — The author states that when a piece of steel develops cracks or soft spots in hardening, the fault is generally laid to the steel, while in his opinion, for which he gives evidences, defective working of the steel is often responsible for it. **No. 83. A.**

**Hardening Special Tools.** E. R. Markham. " American Machinist," December 3, 1903. 1,200 w. — The author calls attention to the care and special manipulations required in hardening certain tools. **No. 84. A.**

**Success in Case-Hardening.** E. R. Markham. " American Machinist," December 3 and December 10, 1903. 3,000 w. — The author describes the methods which in his opinion should be followed to conduct successfully case-hardening operations, including local case-hardening of various implements. **No. 85. Each A.**

**The Works of the Société John Cockerill at Seraing, Belgium.** Emile Guarini. " Iron Trade Review," December 3, 1903. 3,650 w. — An illustrated description. **No. 86. A.**

**Manufacture of Welded Pipe.** Victor Beutner. Paper read before the Engineers' Society of Western Pennsylvania, December 15, 1903. 6,500 w. — An excellent article describing and illustrating the various processes for the manufacture of welded pipes. Reproduced in full in the " Iron Trade Review," December 17 and 24, 1903. **No. 87. Each A.**

**Some Troubles with Samples of Iron and Coke.** Geo. C. Davis. Read at the December meeting of the Philadelphia Foudrymen's Association. 1,560 w. — The author calls atten-



See Abstract No. 93.

tion to the troubles resulting from unsatisfactory sampling of pig iron and defective packing of drillings which are to be sent by mail or otherwise, and suggests precautions to be taken. Reproduced in full in " The Iron Age," December 17, 1903. **No. 88. A.**

**A Modern German Foundry.** " The Foundry," January, 1903. 2,300 w. — A description of the foundry of Ludwig Loewe & Co., of Berlin, giving a clear outline of modern German foundry practice. **No. 89. A.**

**Cutting Speeds and Feeds with the New Tool Steels.** Oberlin Smith. " Engineering Magazine," January, 1903. 5,000 w. **No. 90. B.**

**Mechanical and Metallurgic Applications of Aluminothermics.** Emile Guarini. " Engineering Magazine," January, 1903. 1,200 w. **No. 91. B.**

**The Largest Steel Plant in the World.** " The Iron Age," January 7, 1903. 13,200 w. — Works of the Lackawanna Steel Company, Buffalo, N. Y. A very full, illustrated description of this large plant. The photograph of a Bessemer blow on preceding page is reproduced because of its unusual ecellence. **No. 92. A.**

# EDITORIAL COMMENT

Robert Abbott Hadfield was born in Sheffield,
**Robert Abbott** England, in 1859, the son of Robert Hadfield, a
**Hadfield** descendant of an old Sheffield family and the
founder of the Hecla Steel Works. At an early age he gave evidences of a pronounced taste for chemical and metallurgical researches and in this he received the encouragement and assistance of his father. After having been educated at the Sheffield Collegiate School he entered the Hecla Works, where he devoted himself at first more particularly to laboratory work, but soon assumed much of the responsibility of managing this large and growing plant. In 1888 the firm was reorganized under the name of Hadfield's Steel Foundry Company, Ltd., and Mr. Hadfield became its chairman and managing director, a position which he still occupies. The company has a capital of £400,000, and the shares issued at £1 are now worth £3.5. Two plants are in operation, the Hecla and the East Hecla Works, giving employment to some 3,000 to 4,000 workmen and covering an area of nearly 90 acres. They are said to be the largest makers of projectiles in the world, their product having been adopted on a very large scale by the British Admiralty and War Office. Their foundry is also said to be the largest in existence, being over 1,000 feet in length, with an area of nearly 300,000 square feet. Mr. Hadfield's admirable series of papers on iron alloys, his discovery and commercial development of manganese steel, as well as his many other contributions to the progress of steel metallurgy are too well known by our readers to demand here more than a passing notice. Aside from its industrial value manganese steel has attracted the attention of many distinguished students, chiefly because of its non-magnetic condition, and the investigation of its properties has been most fruitful in valuable results. The believers in the Allotropic theory of iron have found in its behavior strong support for the accuracy of their hypothesis. Mr. Had-

field's achievements have brought him many tokens of appreciation from scientific and technical societies.

The Institution of Civil Engineers awarded to him on different occasions the George Stephenson gold medal and premiums, and the Telford gold medal and premiums, and, in 1903, the Howard prize and premium, which is awarded only once in five years, and which had been previously conferred on Sir Henry Bessemer, Sir William Siemens, Dr. Bauermann and Sir Lothian Bell. Mr. Hadfield also received two gold medals from the Société d'Encouragement pour L'Industrie Nationale and the John Scott medal of the Franklin Institute.

In 1899-1900 Mr. Hadfield was master cutler of Sheffield, in which capacity he entertained Lord Lansdowne, then Secretary of State for War. He is a justice of the peace for Sheffield, a director of several companies and a member of numerous scientific societies. He has for several years been a member of the Council of the Iron and Steel Institute, and this year has been elected vice-president of this society.

The facts which we have here so dryly enumerated suggest the successful life of a worker endowed with much intellectual power, of a worker whose achievements have brought him at an early period in life, not only commercial success, but the many marks of appreciation from his co-workers which he so richly deserves. There is much that is gratifying and refreshing in this thought. It should be a stimulus to the younger metallurgists about to enter into their life's work.

If we were to pass any criticism upon Mr. Hadfield's methods we would venture the opinion that they are characterized by great thoroughness and by a praiseworthy respect and appreciation for the work of those who have preceded him in his various researches. The historical portions of Mr. Hadfield's papers are always full of interest and instruction. Before undertaking a new line of investigation, he carefully studies the results obtained by his predecessors and thus secures a sound foundation upon which to build. Such a course cannot be too highly commended.

**The Brittleness of Steel**   The bulk of the specifications drawn by users of steel have in view the prevention of brittleness. It is chiefly to protect themselves against this dreaded property that so many clauses are introduced rela-

ting to the processes of manufactures, the chemical composition, the physical properties, etc. Until quite recently the ordinary tensile test was the only one readily available to ascertain the absence or presence of brittleness in the metal. If the metal broke with little or no distortion, it was assumed to be brittle, while if it underwent much distortion before rupture took place, the metal was thought to be tough and ductile. Engineers know, however, that steel frequently fails in use through apparent brittleness, notwithstanding the fact that the tensile test had revealed considerable ductility, judging by the amount of elongation obtained. Test bars cut from the vicinity of the fracture after such failures and subjected to the tensile test frequently exhibit much ductility.

It is, therefore, quite evident that the ordinary tensile test is unsatisfactory for the purpose of ascertaining positively the absence of brittleness in steel, of that kind of brittleness at least which may lead to sudden rupture when the metal is in use. Engineers learned long ago to mistrust the results of the tensile test, hence the constantly increasing requirements of other nature introduced in the specifications. The urgent need of a better test will be conceded, we believe, by most manufacturers and users of steel. Impressed by this unreliableness of the tensile test, several eminent French engineers, notably Messrs. André Le Chatelier, Frémont, Charpy, Guillery and Le Blanc endeavored to devise a method of testing which would indicate more positively absence of brittleness in use. The test which they devised consists in nicking the test bar in the middle and then breaking it by impact while supported at both ends. The size and shape of the bar as well as the depth and width of the nick are matters to be agreed upon. Our distinguished special contributor, Prof. H. Le Chatelier, has written for this issue an excellent presentation of the character and merits of this new test. Its superiority over the tensile test has been quite universally proved. In France and to a less degree in Germany and in England, metallurgists and engineers have welcomed the new test, and in these countries it has in several important instances been introduced into specifications. American engineers have not so far given to this departure in the testing of steel the attention which it deserves, and it is to be hoped that Professor Le Chatelier's timely article will be instrumental in impressing them with its importance.

Dr. C. B. Dudley, the eminent and experienced chemist of the Pennsylvania Railroad Company, sums up elsewhere in this issue, in a most satisfactory manner, our present knowledge of the fracture of steel when subjected to a great many alternate stresses of relatively small magnitude. It was discovered long ago that alternate stresses, especially of a bending character, even when these stresses were apparently much below the yield point of the metal, if continued long enough, eventually caused the fracture of the steel, but although this subject has for many years engaged the attention of metallurgists and engineers, Dr. Dudley rightly points out that we greatly lack information of a positive nature both as to the cause of the phenomenon and the relation between the intervening factors. " Sooner or later," the author writes, " if the stress is high enough, all metals will rupture under alternate bending stresses." If the stress is high enough! This suggests the question: What is the minimum alternate stress which will eventually cause rupture? What relation does it bear to the tenacity and the elastic limit of the metal? The opinion has been expressed by experienced engineers that alternate stresses will not cause fracture, unless each application of the stress produces a permanent set. At first sight it would seem as if this meant that if the stress be below the elastic limit of the metal, as we are accustomed to determine it, it can be continued indefinitely without producing rupture, a conclusion which is refuted by the evidence we have of the failures of many steel implements when under loads apparently much smaller than the elastic limit. And still is not the statement correct, provided we have in mind the theoretical elastic limit of the metal — and by that we mean the smallest stress capable of producing a permanent set, *no matter how minute*. With our most delicate instruments a permanent set must reach a certain magnitude before we are able to detect it. Could we devise measuring apparatus of greater delicacy we would be able to detect smaller permanent sets, and the apparent elastic limit of the metal would be correspondingly lowered. Can it not be said, then, that each application of repeated alternate stresses must produce a permanent set in order to cause rupture, provided we have in mind, not the sets we are able to measure with our instruments, but distortions of much smaller magnitude?

This hypothesis certainly helps us in conceiving the mechan-

ism of the fracture of steel by alternate stresses. To decrease the danger of rupture by such stresses, Dr. Dudley conclusively shows that metals with higher elastic limits should be used, and this falls in line with the hypotheses here alluded to, while it cannot readily be explained without it, for if each application of the stress which is eventually to cause the fracture of the metal, does not produce a small permanent distortion, it is difficult to account for its relation to the elastic limit.

Admitting that each application of the stress must produce a permanent set (however infinitesimal) in order to cause the failure of the steel, the phenomenon becomes comparable to the breaking of a wire by bending it back and forth. Because of the great distortion produced in the wire, but a few applications of the stress are sufficient to break it; while because of the extremely minute distortion of the other samples a great many applications are required. The smaller the permanent set resulting from each application of the stress, the greater the number of applications needed to break the metal with the two extreme cases, corresponding to no permanent set and no failure and to great distortion and immediate failure.

**Iron and Steel Institute at Aachen** The movement inaugurated by Professor Wüst, of the Royal Technical University at Aachen, for an institute devoted exclusively to the training of metallurgists in iron and steel is worthy of serious consideration in this country. Professor Wüst, who is an acknowledged authority upon metallurgical matters, deplores the fact that, although Germany is the third largest producer of iron in the world, there is in that country only two professorships of metallurgy, and neither of these is devoted exclusively to iron and steel. At present, he points out, that the student who contemplates going into the iron business must either take a course in chemistry, in which there is little training in mechanical matters, or in mechanical engineering, in which there is little or no chemistry. In other words, there is no course in which a student may obtain such a working knowledge both of chemistry and mechanics as is necessary to the successful iron and steel manufacturer. In the institute outlined by Professor Wüst, in a recent article in " Stahl und Eisen," an abstract of which is given in this issue of *The Iron and Steel Metallurgist* (abstract No. 48), it is aimed to provide such a course.

We believe that the iron industry, especially in this country, has reached such proportions as warrants a specialization of its study in technical schools, and we hope soon to hear that some one of our large universities has established a course devoted exclusively to iron and steel.

# CORRESPONDENCE

### Influence of Structure of Zinc upon Service Value

*To the Editors.*

An interesting case came up recently upon the Philadelphia & Reading Railway emphasizing the influence which may be exerted upon service value by structure of metal.

Some gravity battery zincs used in connection with track signals had worn away very rapidly in service, and had averaged only about a third of the life usual under the given conditions. As the metal dissolved, relatively large portions of the zinc became loosened and dropped upon the blue stone beneath, and thus reduced the efficiency of the cell.
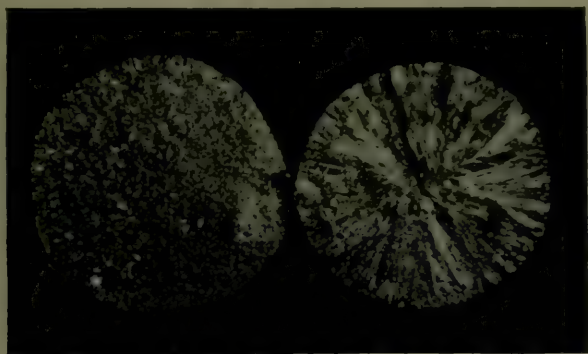


Zinc Fractures.   2 Diams.

The zinc, upon analysis, was found of good quality, but upon examining the structure, a very large coarse granular form was found due to pouring the zinc into the mold at a relatively high temperature.   The fracture is shown to the right of the cut.

Some of the same zinc was then taken, melted and poured at a fairly low temperature, giving the structure represented by the fracture to the left.  Upon putting these zincs in service under

the same conditions as previously, no scaling off occurred, and the zinc wore away gradually, giving the normal life, about three times that averaged by the same material when coarse-grained.

The defective service of the coarse-grained zinc is readily explained if one assumes that under the electrolytic action the liquid penetrated into the zinc along the surfaces of the crystals, and as action progressed, gradually dissolved the metal along such surfaces, and thus finally resulted in the scaling which caused the difficulty.   In the fine-grained zinc no such action was possible owing to the small size of the crystals, and thus a gradual solution of the metal was effected solely upon or very close to the surface, with the result that none of the material was wasted.

Robert Job.

Reading, Pa., Dec. 31, 1903.

# IRON AND STEEL METALLURGICAL NOTES

**History of Nickel-Steel.**— The following brief historical review of the use of nickel-steel is reproduced from a recent publication by Mr. Albert Ladd Colby, entitled " Nickel-Steel and Carbon-Steel," copyrighted by the International Nickel Company, and which is reviewed elsewhere in this issue.

In 1822, Stodart and Faraday published their experiments made at Sheffield in the alloying of nickel and iron. A little later Berthier made some similar experiments in France.

In 1830, Wolf, of Scheinfurt, Germany, put some nickel-iron alloys on the market, which he called " meteoric steels." They were damasked, and Liebig comments on their magnificent appearance in a note in the " Annalen der Pharmacie," and states that this alloy is destined to be developed in the near future.

In 1853, Fairbairn published some experiments undertaken to determine the strength of some alloys of nickel and iron similar in composition to meteoric iron.

At the exposition held in New York in 1853, Philip Thurber exhibited several samples of nickel-steels produced from a nickeliferous limonite.

In 1858, Sir Henry Bessemer made an experimental three per cent nickel-iron alloy, with a view of making what he termed " meteoric iron guns." He did not, however, pursue the subject, nor publicly refer to the matter until 1896.

Percy, in his " Metallurgy," published in 1864, refers to experiments conducted by Richardson in his (Percy's) laboratory on nickel-iron alloys varying from 1.00 to 50.00 per cent in nickel.

In 1870, Alex. Parkes, of Birmingham, took out several patents for the production of alloys of iron and nickel.

In 1883, John Gamgee made nickel-iron alloys in Connecticut.

In 1884, A. M. Clark, of London, patented the manufacture of a malleable ferro-nickel.

In 1885, ferro-nickel was manufactured at Marbeau's Works, at Montatoire, France, under the supervision of Betheault.

In 1887, highly carboniferous nickel-steels were made experimentally at the Steel Works at Imphy, France.

In 1888 and 1889, several French and English patents for the manufacture of nickel-steel, and its applications, were granted to Marbeau, Schneider, Riley and Hall.

It is, therefore, evident that the advantages of alloying nickel with iron and steel have been known for some time. The credit of making the first systematic series of practical tests on nickel-steels belongs to Mr. James Riley, then of Glasgow, whose elaborate paper on " The Alloys of Nickel and Iron " was read by him before the Iron and Steel Institute of Great Britain on May 8, 1889. From a discussion of this paper it appears that J. F. Hall, of Sheffield, had been working on similar lines to Mr. Riley, but his results had not been publicly put on record. Mr. Riley's paper gave the impetus to the introduction of nickel-steel in a commercial way.

Since then steels, with 2.00 to 5.00 per cent in nickel, have been used for armor plate, ordnance, marine, locomotive and stationary engine forgings, and many other purposes where severe service is required. The higher nickel-steels have also been introduced for many special purposes.

Another epoch in its history has just been reached by the adoption of three to three and one-half per cent nickel-steel rails for sharp curves and by the serious consideration of a three to three and one-half nickel-steel for bridge construction. The fact that this is considered commercially practicable, and that this report is written with a view of showing the advantages which will be gained by the use of nickel-steel in bridge construction, is a striking commentary on Professor Ledebur's prophecy, in 1889, that Mr. Riley's discovery of the valuable properties of nickel-steel belongs to that class of inventions which appear at greater or less intervals, finally to be buried in oblivion because of their impracticability.

Since Riley's practical and suggestive paper the technical

men of many steel works in France, Germany, Great Britain
and America have made nickel-steel, studied its physical
properties and put it on trial for a wide variety of purposes.
In this work they have been aided by consumers looking for
a better material, and by the scientists connected with the
technical universities in each country, as well as other inde-
pendent investigators. The result is that a large amount of
valuable information on the properties of nickel-steel com-
pared with carbon-steel, as well as the reports of its trial in
service, have been published since 1888, in the French, Ger-
man and English periodicals, and in the proceedings of the
technical societies of each country.

**Krupp Patents for Increasing Strength.**\* — Among the
recent patents taken out by the Krupp works at Essen are
two directed at increasing the strength of metals. The first
deals with malleable iron for electrical machinery where a
high degree of permeability is required, and the end is
attained by adding to the malleable cast iron (containing
about 0.1 to 0.25 per cent of carbon) a comparatively large
amount of silicon, say, from one to four per cent. The silicon
is best added to the malleable cast iron in the form of ferro-
silicon just before casting. Such a malleable cast iron has,
in addition to a substantially greater strength, a high per-
meability, which renders it suitable for large machines run-
ning at a great number of revolutions.

The other patent relates to spring steel containing 0.4
to one per cent of carbon, and a comparatively large amount
of silicon, say, between one and four per cent, added to it.
The raw material may be quite ordinary Martin steel, to
which the required silicon is best added in the form of the
cheap ferro-silicon, prior to casting. Experiments show that
hardened steel of this composition possesses an increased
strength.

**Iron Manufacture in the Transvaal.**† — " The African
World " announces the erection of the first blast-furnace in
Africa. It is expected to be blown in about February next.

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\* "Iron Trade Review," November 26, 1903.
† " The Colliery Guardian," December 4, 1903.

Some six months ago great interest was created by the discovery of workable iron ore deposits in the Lydenburg district of the Transvaal, which has since been acquired by Rand capitalists, but transit difficulties have postponed development of the property. In the meantime, the Lydenburg discoveries have been eclipsed by the location of rich iron ore deposits within a radius of a dozen miles from Pretoria itself, the railway line actually passing through the property. The territory in question, extending, with adjacent coalfields and other properties, over twenty square miles, has been acquired by a syndicate. A furnace, which will have a capacity of 500 tons of pig iron weekly, is now being constructed, and in addition there is to be a complete installation of rolling mills for the production of rails and merchant sections, and black sheets for galvanizing, etc. A steel-converting plant has also been arranged for. By above-ground survey and cross-cutting it has been estimated that about 62,000,000 tons of iron are actually in sight. The ore is of the hæmatite and magnetic varieties, assaying from 58 to 62 per cent of metallic iron. The syndicate have acquired an adjacent colliery in full working order, which produces an admirable coal for smelting, whilst abundance of limestone lies close by. A large deposit of manganese ore has also been acquired by the syndicate, which proposes to ship large quantities of this ore to England and elsewhere.

**Controlled Cooling of Castings.** * — The drawing herewith is from a United States patent recently issued to William A. Bole, superintendent of the Westinghouse Machine Company. The invention relates to means for cooling a casting locally while still in the mold and regulating or controlling the relative cooling of different portions. The specification says:

"In making castings which comprise unequal thicknesses of metal, particularly if the castings are of large size, some portions will cool more rapidly than others, and it follows that the thicker and heavier sections continue to contract after the thinner sections have assumed their final dimensions,

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* American Machinist," December 3, 1903.

strains being thus produced in the castings which are some-
times so serious as to cause the castings to rupture, even
while in the mold, and sometimes giving no visible sign of
their existence until the skin of the castings is removed by
machining, when the internal stresses produce a rupture of
the casting. Cases have been known in which the rupture
due to internal strains took place months after the castings
were made and without any previous visible indication of the
existence of such strains.
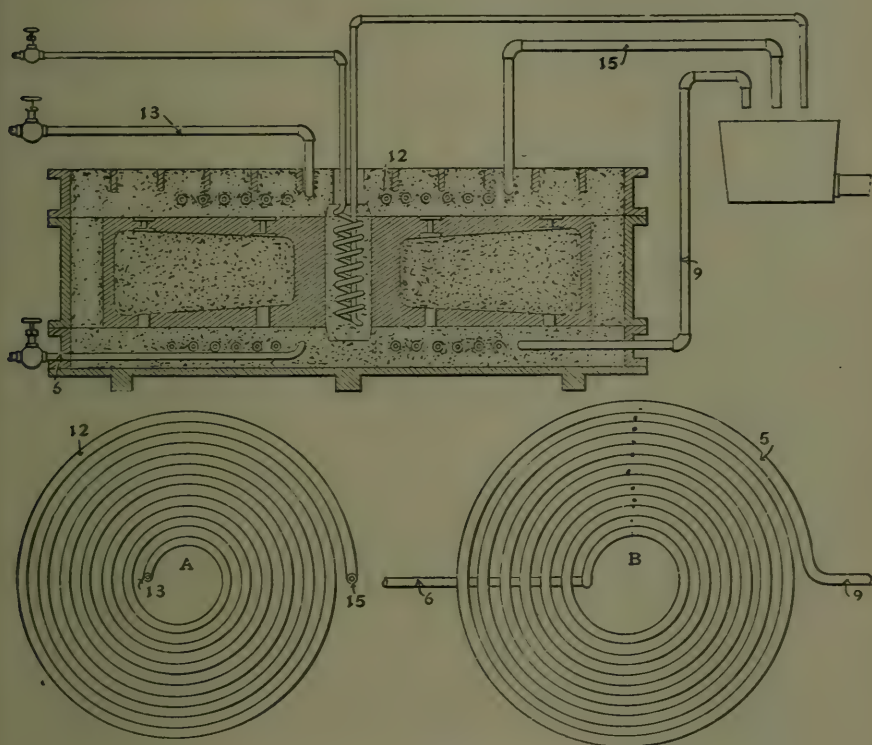


Controlled Cooling of Castings.

" In the case of castings having different portions of un-
equal thickness, the thicker portions obviously cool and
solidify much more slowly than the thinner portions, this
being specially pronounced where the outer portions are the
thinner ones, since the more rapid cooling incident to the

lesser thickness of the metal is further enhanced by the more ready radiation of heat toward the outer surface of the flask or of the mold. By reason of this unequal cooling lack of uniformity of crystalline structure and consequently unbalanced strains are present in the casting. I avoid these difficulties by artificially cooling the thicker portions of the casting, which would naturally cool slowly, and independently regulate the cooling effect at different points, so as to secure an approximately uniform rate of cooling throughout the casting."

The drawing shows in section a mold containing a large piston, the thicker portions of which are the hub and the parts near it and the thinnest at the periphery, the latter naturally cooling the most rapidly. To cool the inner and central portions of the casting as rapidly as the periphery, water-pipes are placed in the mold and water is circulated through them immediately after the pouring of the metal. The spiral pipe *A* is rammed in the sand of the cope and *B* in the drag, while a vertical helical pipe is placed in the hub-core when that is made. When the mold is completed, pipes are connected to the water supply and also to a receptacle for the overflow. A flow of water is started through the pipes immediately after the pouring of the metal, the flow in each being regulated by the valve according to the judgment of the operator, which may be assisted by feeling of the overflow pipes and noting the temperature. The form, number and location of the cooling pipes must be determined by the size, shape and requirements of the casting. When judiciously placed and used they can evidently be made to produce practically synchronous cooling of a casting, or they can be made to cool some part in advance of some other part, as, for instance, the centre before the periphery, so that when the latter cools it may serve to bind the structure together as a tire binds a wagon wheel.

**American Sheet Steel Company and American Tin Plate Company.** — The business of the American Sheet Steel Company and American Tin Plate Company will hereafter be conducted under the name of American Sheet and Tin Plate

Company, with the following organization: George G. Mc-
Murtry, chairman of the Board of Directors; W. T. Graham,
president; W. M. Leeds, first vice-president; E. W. Pargny,
second vice-president and manager of sales; W. P. Beaver,
assistant to president; John Warner, assistant to first vice-
president; Howard M. Davis, assistant manager of sales; H.
B. Wheeler, secretary and treasurer; H. L. Austin, auditor;
G. M. McGinnis, assistant auditor; C. W. Bray, chief en-
gineer, Pittsburg; R. A. McKinney, purchasing agent, Pitts-
burg. The general offices of the company will be moved from
Battery Park Building, New York, to Pittsburg early in 1904.

**American Institute of Mining Engineers.** — The eighty-
sixth meeting of the Institute (being the twenty-fourth annual
meeting) will be held at Baltimore, Md., beginning Tuesday
evening, February 16, 1904. The sessions of this meeting will
be devoted largely to papers and discussions relating to iron
and steel, without excluding, however, the acceptance for
publication of suitable contributions on other subjects, or
their presentation and oral discussion if time permits.

At the close of this meeting an excursion is proposed to
Cuba and Porto Rico, provided a sufficient number of mem-
bers and guests will take part. For this purpose an option
has been secured for the charter of the large and comfortable
steamship Friesland of the American Line, to sail from Balti-
more on Monday, February 22, for a trip of 25 days, including
a stop at Havana (long enough for a reception by the Presi-
dent of Cuba), a picturesque sail along the southern coast
of Cuba to Santiago de Cuba; a visit to the Santiago iron and
manganese deposits, etc.; a visit of several days in Porto
Rico and a stay of one day each at Fort de France, Martinique
and at St. Pierre, permitting an inspection of the regions of
the late volcanic eruptions, and a return to New York City.

# REVIEW OF THE IRON AND STEEL MARKET

The advent of the new year was eagerly awaited in iron trade circles. The iron market moves by sentiment rather than by logic or statistics, and predictions had been made that after January 1 there would be a turn from the downward movement which characterized practically the whole of 1903. January was therefore expected to be a crucial month; if it did not show an improvement, sentiment was that no early improvement could be expected.

It is gratifying to be able to record that since the first of the year there has been a notable increase in demand for a number of finished steel products, which has given a more hopeful tone to the whole market.

In the fundamental material, pig iron, the condition is mixed, and judgment must be suspended. There has been a large increase in the number of active furnaces, accompanied by a slight decrease in market quotations, and very little new buying. The question is whether the increased activity is due mainly to the lowering of cost of production due to cheaper coke and reduced wages, or mainly to prospects of an increased demand. That both factors have contributed is certain; but the matter which predominates is a subject for debate. The southern furnaces are, as nearly always, a disturbing factor. They move in a class by themselves, and the northern iron industry does not always speak complimentarily of southern business ability. The southern blast-furnaces are sold up fully to some time in March, the bulk of the material having been sold at from $9 to $9.25, f.o.b. Birmingham for No. 2, with a smaller quantity at $9.50 and a negligible amount at $9.75. They have now advanced their asking price to $10 and expect to obtain this figure when it becomes necessary to resume selling. This would mean $13.85 delivered Chicago and $14.35 delivered Pittsburg. They are even talking $10.50 to $11.00 for second quarter. At $10 they are above northern iron by 50 cents, delivered Pittsburg, and below by 15 cents, delivered Chi-

cago. As consumers expect to buy southern iron at slightly less than northern, it is evident that by the time the southern furnaces need any large additional tonnage the northern market must have advanced, or they will be forced to reduce their price. In the latter event the reduction would act to delay buying until consumers were assured bottom had been reached, and while this bottom was between $8.75 and $9 in November, there have been wage reductions meanwhile, and southern iron costs are almost entirely a matter of wages. Neither freights nor depreciation of property due to mineral exhaustion figure to anything like the extent they do in the northern pig-iron industry, so that there is a distinct possibility that later on a decline in southern pig iron may act as a brake to the whole pig-iron industry.

The low point in pig iron production was reached on January 1. On that date the Illinois Steel Company had only two of its 18 furnaces in blast; in the first three weeks in January it has blown in at least three additional furnaces. The Carnegie Steel Company had the majority of its furnaces idle; in the same period it has blown in 13 furnaces, as follows: One Sharon stack, one Shenango and one Rosena, both at Newcastle; one Ohio stack, at Youngstown, and in the Pittsburg district two Carrie, five Edgar Thomson and two Duquesne. J. G. Butler, Jr., of Youngstown, chairman of the Bessemer Furnace Association, composed of a number of merchant furnace interests in the two valleys, has reports that of 156 furnaces in the Central West, 91 were idle on December 1 and 103 on January 1, showing a drop in active capacity from 42 per cent to 34 per cent. During January there has been an increase, but returns are not available showing its extent.

Pig iron prices are as follows: At Birmingham — Foundry, No. 2, $10 to $11, with 50 cents between grade numbers; forge, $8.75 to $9.75. At Pittsburg — Bessemer, $13.85 to $14.10; foundry No. 2, $13.85 to $14; forge, $12.75 to $13; southern foundry No. 2, $14.35 to $15.35, f.o.b. Mahoning or Shenango valley furnace — Bessemer, $13 to $13.25; foundry No. 2, $13; forge, $12. At Chicago — Northern foundry No. 2, $14 to $14.25; malleable Bessemer, $14.50 to $14.75; Lake Superior charcoal, $16.50 to $17; southern foundry No. 2, $13.85. At Philadelphia — Foundry No. 2x, $14.75 to $15; No. 2 plain, $14 to $14.25; southern foundry No. 2, $13.75 to $14 for rail shipment and $13 to $13.25

on dock. Low-phosphorus pig iron is about $18 at furnace, and ferro-manganese $46 in carloads, and $44 to $45 in large lots, delivered anywhere east of Mississippi River.

The increased purchases of certain finished steel lines is largely forced by the fact that stocks are extremely small all over the country. There is necessarily a certain amount of consumption all the time, necessitating small and frequent orders being placed. There is no buying ahead of moment, except in wire, where before the advance announced January 11 there was covering to March 1. Outside of wire, the most active finished line has been merchant bars, both iron and steel.

The principal drag on the market appears to be the fact that while pig iron and crude steel have had a great decline, and certain finished lines, notably merchant bars, sheets, light rails and hoops and bands, have suffered a large reduction, standard rails, structural shapes and plates are all three held at the official prices which were established early in 1901 and have been maintained without official change until now. The railroads refuse to contract for the coming season at the $28 price, and have even canceled orders placed last summer, and orders placed for 1903 but held over by mutual consent some time ago. In shapes there is likewise uncertainty as to the possibility of avoiding a reduction, and bids on finished structural work have been made by erectors on an extremely small margin above the mill prices of the sections. In plates there has been cutting of the association price, by finishing mills buying slabs in the open market. The large interests in these three important lines propose to ignore the sentimental reasons for lower prices and hold the official rates by main strength. It is for the future to determine whether they will succeed.

January 7 the Cut-Nail Association met and reduced the official price 20 cents, to $1.70 a keg, base, for either iron or steel cut nails, carload or larger lots, f.o.b. Pittsburg, plus freight to destination. The actual cut was not over 10 cents a keg, since the former official price was being shaded by at least that amount.

January 11 the leading wire interest and the only two important outside interests announced an advance on all wire products of five cents a hundred. The market is absolutely firm at the advance, which makes prices, in ordinary carload lots, f.o.b. Pittsburg, plus full rail freight to destination, 1.75c, base, per pound, for plain wire, and $1.85 per keg, base, for wire nails.

Very large jobbers get a special concession of five cents a hundred below these figures.

January 11 the bi-monthly wage settlement for the central western iron mills disclosed an average price of shipments of common iron bars during November and December of between 1.3 and 1.4 cents, fixing puddlers' wages at $5.25 for January and February, and reducing finishers' 4 per cent. The previous bi-monthly settlement had disclosed a rate between 1.5 and 1.6 cents, giving puddlers $5.75 per ton.

January 12 the merchant steel bar association met at the Union Club, Pittsburg, and by a narrow majority voted down a proposition to advance the price $1 a ton, thus reaffirming the price at 1.30 cents.

*Billets.* — Association prices: 4 × 4 and larger Bessemer or open-hearth billets, carbon up to and including 0.25 per cent, delivered, Pittsburg, Wheeling, valleys, Johnstown, Ashland, Lorain, $23; Philadelphia and Baltimore, $24.25; Chicago, $24; Cleveland, $23.50; New York, $24.75; advances: carbons, 0.26 to 0.60 per cent, $1; 0.61 to 1.00 per cent, $2; billets 3⅞-inch and smaller, and sheet bars, long lengths, $1; cutting sheet bars to specifications, 50 cents. Wire rods are $30.

*Merchant Bars.* — Steel, 1.30 cents, half extras, carload or larger lots, f.o.b. Pittsburg, plus full rail freight; common iron, 1.25 cents, half extras, carload or larger lots, f.o.b. Ohio mill.

*Plates.* — Official prices: Tank quality, one-quarter-inch and heavier, 100 inches wide and narrower, 1.60c, carload or larger lots, f.o.b. Pittsburg, plus full rail freight; advances: three-sixteenths-inch, 0.10c; wider than 100 inches, 0.05c; flange and boiler quality, 0.10c; ordinary firebox, A. B. M. A. specifications, 0.20c.

*Shapes.* — Zees, angles, 3 to 6-inch, beams and channels, 3 to 15-inch, 1.60c; tees, 1.65c; beams and channels, 18 to 24-inch, 1.70c, all carload and larger lots, f.o.b. Pittsburg, plus full rail freight.

*Sheets.* — Ordinary carloads, f.o.b. mill, No. 28 gauge; black, 2.30c; galvanized, 3.35c; large lots, about 0.05c concession.

# RECENT PUBLICATIONS

*Materials of Machines,* by Albert W. Smith, Professor of Mechanical Engineering in Leland Stanford Junior University; 142 7½ × 4½-inch pages. Illustrated. John Wiley & Sons, New York, 1903. Price, $1.00. — This little book, the author says, is a result of an effort to bring together concisely the information necessary for the selection of materials for machine parts. It includes a very satisfactory outline of the metallurgy of iron and steel and deals concisely with the properties and testing of iron, steel, cast iron and engineering alloys. The last chapter is devoted to the selection of material for the various parts of machines. On page 43, Bessemer steel is said to be " very similar to wrought iron in chemical composition, but usually containing a little more carbon." Inasmuch as the bulk of the Bessemer steel manufactured is rail-steel, this resemblance to wrought iron will hardly be accepted by metallurgists. It also states on the same page that wrought iron is made up of fibres of iron covered with slag. The author falls here into the common erroneous belief in the fibrous structure of wrought iron, although it has been shown repeatedly that the iron forming the bulk of wrought iron is just as crystalline as the iron found in low carbon steel. Its structure does not show any trace of the metal being drawn into fibres by rolling, the slag alone being so affected. On page 103 the author thus describes the annealing of forgings: " After forging, the piece should be allowed to cool to V or below; its temperature should then be slowly and uniformly raised to W; it should then be quenched to V, and allowed to cool slowly in the air." The author also stipulates the necessity of cooling slowly through V. If it be remembered that between W and V there is only a range of temperature of some 75° C., the operation here described is certainly a remarkable *tour de force.* Notwithstanding these necessary criticisms, however, this little book, because of its conciseness and clearness, commends itself highly to those who would acquire an elementary knowledge

of the metallurgy, the properties and the testing of iron and steel, so as to select more intelligently the metals which they need. The book is gathered up with the usual care bestowed by John Wiley & Sons to all their publications.

*The Copper Handbook.* A Manual of the Copper Industry of the World, Vol. III for the year 1902. Compiled and published by Horace J. Stevens, Houghton, Mich.; 600 5½ × 8½-inch pages. Price, $5.00. — This valuable annual publication has won an enviable place in metallurgical literature. It contains much which is of value to any one interested in copper in whatever capacity, and it is evident that the author strives to make each volume better than its predecessor. The present issue is divided into sixteen chapters dealing respectively with the History of Copper, the Geology of Copper, the Chemistry and Mineralogy of Copper, the Metallurgy of Copper, the Ores of Copper, Glossary of Mining Terms, Copper Deposits in the United States, Copper Deposits of Canada and Newfoundland, Copper Deposits of Mexico, Central America and the Antilles, Copper Deposits of South America, Copper Deposits of Africa, Copper Deposits of Asia, Copper Deposits of Australia and Oceanica, Copper Mines of the World, and Statistics of Copper.

*The Mechanical Engineer's Reference Book.* A Handbook of Tables, Formulas and Methods for Engineers, Students and Draughtsmen, by Henry Harrison Suplee; 834 4 × 6½-inch pages. Illustrated. J. B. Lippincott Company, Philadelphia and London. Price, $5.00; with patent thumb-index, $5.50. — The book is divided into the following sections: Mathematics, Mechanics, Materials of Engineering, Strength of Materials, Machine Design, Heat, Air, Water, Fuel, Steam, Steam Boilers, Steam Engines, Internal-Combustion Motors, Electric Power, The Cost of Power, Works Management. It would be difficult to praise too highly this most valuable addition to engineering reference books. It was in course of preparation for a number of years, and the publishers report so great a demand for it before the date of publication that a second printing was required. The book is neatly bound with flexible cover, is gilt-edged, and the special thumb-index greatly adds to the readiness with which any desired section may be consulted. Typographically it could hardly be improved, and the publishers are to be congratulated on the production in so attractive a form of so useful a book.

*Metallurgical Analysis and Assaying,* by W. A. MacLeod and Chas. Walker; 318 6 × 9-inch pages. Illustrated. Charles Griffin & Company, London, 1903. Price $4.00. — The authors in their preface state that this book was prepared to meet the requirements of students of Schools of Mines, the subject-matter being selected to cover a period of three years' laboratory work. The aim of the work is to provide the student with a general course of work, leading from single qualitative analysis to the technical quantitative methods employed by the modern metallurgical chemist, and treated in more advanced works. The authors claim no originality of matter, but simply novelty in arrangement, which they hope may be of service both to the teacher and the student. Part I deals with the qualitative analysis, preparation and properties of gases; Part II, with methods and manipulations used in qualitative and quantitative analysis in general; Part III, with assaying and with the technical analysis of water, furnace gases, ores, coal and coke, fire-dogs and cements, oils, iron and steel and copper and lead slags. The plan of this book is excellent, and the authors are to be congratulated on the production of a work invaluable to students and in which technical analysts also will find much that is of interest and value.

*Steel and Iron for Advanced Students,* by Arthur H. Hiorns; 514 4½ × 6½-inch pages. 131 illustrations. Macmillan & Company, Ltd., London, 1903. Price, $2.50. — The author states in his preface that he has keenly felt the need of a text-book, dealing with the more scientific aspects of the metallurgy of iron and steel, for the use of students, and that this book is an attempt to supply such a need. He rightly adds that the sub-title, "for advanced students," is not intended to convey the idea that the book is of a highly advanced character, but that it is not an elementary book for beginners. The subject is treated quite exhaustively and in many respects very satisfactorily; a reasonable amount of space is devoted to recent scientific research. The few pages devoted to the microscopic structure of iron and steel are disappointing and contain some exceedingly poor reproductions of poor photomicrographs. With this exception, this new publication constitutes a very good and up-to-date text-book of the metallurgy of iron and steel.

*Nickel-Steel and Carbon-Steel.* A comparison of certain of their physical properties, by Albert Ladd Colby; 104 8 × 10½-inch pages. Illustrated. Paper cover. Copyright by the International Nickel Company, 1903. — This excellent contribution to the already voluminous literature on nickel-steel by so expert a writer will be welcome to all those interested in this valuable iron alloy. The comparison between carbon-steel and nickel-steel includes the following properties: modular of elasticity, tensile strength, compression, cold and quench bending tests, rigidity, hardness, expansion on heating, segregation, effect of punching, and effect of shearing. Mr. Colby's conclusions are mainly based on numerous experiments carried on in various countries and the results of which are scattered among a great many publications, carefully prepared bibliographies being appended to each section. The author confines his attention to steel containing two to five per cent of nickel.

*The Manufacture of Iron and Steel Tubes,* by Edward C. R. Marks; 156 4½ × 6-inch pages. 133 illustrations. The Technical Publishing Company, Ltd., London, 1903. Price, $2.00. — This is the second and enlarged edition of a book of great interest to manufacturers and others interested in iron and steel tubes. It presents in a concise and yet exhaustive manner the advance made in this important manufacture as illustrated by the numerous patents obtained by inventors from the Osborn patent, granted in 1812, " for machinery for welding and making barrels of firearms and after cylindrical articles," to the most recent awards of patent offices.

*Annual Report of the Smithsonian Institution,* for the year ending June 30, 1902; 687 pages. Profusely illustrated. Government Printing Office, Washington, 1903. — This excellent annual publication contains, besides the secretary's report, the usual number of valuable articles and fine illustrations.

# PATENTS

## Relating to the Metallurgy of Iron and Steel

### UNITED STATES

744,874. COOLING-BED FOR METAL BARS OR RODS.— Marvin A. Neeland, Youngstown, Ohio, assignor to Morgan Construction Company, Worcester, Mass. In a cooling-bed for metal bars, or rods, the combination of the following instrumentalities: Means for severing the bar into desired lengths, means for assembling the several lengths into groups of parallel bars, means for moving the bars in a group simultaneously by an endwise movement, means for checking the endwise movement of a group at a desired point, and means for moving the bars in the group by a sidewise movement.*
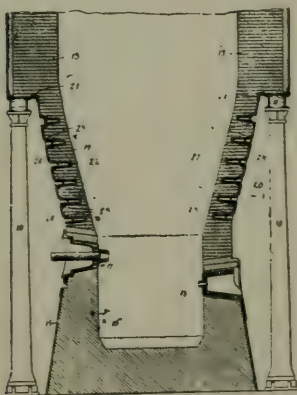


745,430. SUPPORT JACKET OR FRAME FOR COOLING PLATES OR COILS IN BLAST-FURNACES.—A. Farrell, Gladstone, Mich. Blast-furnace, bosh wall of which is encircled by metal jacket having series of superposed holes formed therein, holes being separated by integral portions of jacket, jacket being provided with projecting supports about holes, and cooling plates or coils extending into body of bosh wall and suspended at outer ends by supports of jacket.†

746,055. COKE-DRAWER.— David Ferguson, Pittsburg, Pa. In a mechanical rake or drawer, a drawer-bar, a rake carried there-by and having movement transversely thereof, means connected to said rake and to said bar which initially causes the rake to travel transversely of the bar, and when the travel of the rake has reached a limit



causes the bar with the attached rake to travel longitudinally.*

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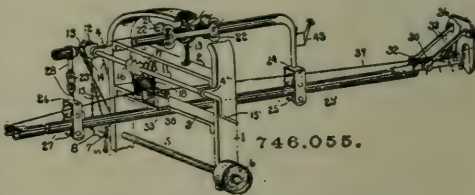
* "Engineering and Mining Journal."   † "Mining and Scientific Press," December 19, 1903.

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746,039. Process of Producing Carbon-Steel Castings. — James C. Davis, Chicago, Ill., assignor to the Sargent Company, Chicago Ill. A described process of making hardenable steel castings consisting in reducing the metal to a molten state, pouring the same into a mould, and during the act of pouring, introducing a finely divided hardening element of higher specific gravity, into the metal, and thoroughly distributing the hardening element through the steel, in proportion to render the casting capable of being tempered to uniform hardness.*

746,235. Slag-Boiler. — Ralph Baggaley, Pittsburg, Pa. Apparatus for extracting heat from slag and discharging the solidified slag, which consists in the combination with a slag-heated steam boiler, having a slag tube or tubes extending from the upper to the lower portion thereof and having an opening for the reception of molten slag, of means set below the boiler in line with the tube and adapted to support and crush the solidified column of slag, said crushing means being supported independently of the boiler structure.*

746,281. Manufacturing Steel. — Charles V. Burton, Fulham, England, assignor of one-half to William John Hartley, London, England. A process for the carbonization of steel which consists in blowing acetylene diluted with a less explosive diluent gas through molten metal.*

746,442. Machine for Making Wire Hoops. — Albert J. Bates, Joliet, Ill., assignor to the American Steel & Wire Company. In a wire-hoop machine, the combination of an upper feed-roll, a yoke in which it is mounted, pivoted arm, a rod adjustably connected therewith, a lever, a cam for operating the lever, and a spring on the rod.*

746,814. Method of Extracting Moisture from Air for Blast-Furnaces and Converters. — Jas. Gayley, Braddock, Pa. A method of feeding air to blast-furnaces or converters, which consists in drawing the air through a chamber, and cooling it in said chamber to o° C., thereby causing its moisture to be eliminated or reduced to a small and practically uniform percentage, thereafter causing the dried air to pass into the blowing engine, then feeding the dried air into the furnace or converter, and maintaining it constantly under compression from the time it leaves the blowing engine until it enters the furnace of converter.*
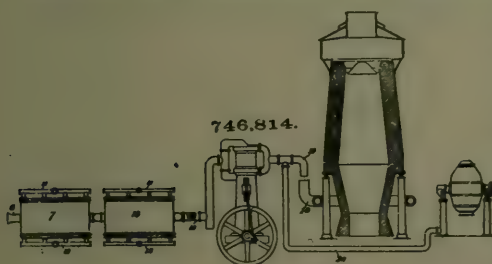
746,886. ROLLING MILL FEED TABLE. — Edwin E. Slick, Pittsburg, Pa. The combination with a rolling mill, having passes at different levels, of a table or trough extending outwardly from a pass at a lower level, a downwardly-inclined trough or table extending down from an upper pass into the path of the metal on the lower table, and having at least a portion thereof arranged to swing, and mechanism for feeding the metal outwardly on the lower table to a point beyond the lower end of the inclined trough.*

747,019. CRUCIBLE FURNACE. — James D. Swindell, Pittsburg, Pa., assignor to American Furnace and Machine Company, Pittsburg. In a furnace, the combination with a combustion chamber having an opening in its roof, of a movable bottom, and means for raising said bottom into contact with the roof of the combustion chamber to prevent escape of furnace gases.*

747,661. MANUFACTURE OF OPEN-HEARTH STEEL. — Benjamin Talbot, Pencoyd, Pa. In the manufacture of open-hearth steel, the process which consists in providing a furnace with a bath of refined or partially-refined iron or steel having a covering of basic slag, adding carbon and metallic oxide thereto, adding molten iron or steel containing metalloids thereto, and withdrawing metal from the furnace when refined to the extent required.*

747,662. MANUFACTURE OF STEEL. — Benjamin Talbot, Harrogate, England, assignor to Continuous Metal Refining Company, Philadelphia, Pa. In the manufacture of steel the process which consists in producing an oxidized steel-bath, providing said bath with a basic slag, charging molten iron into said bath, decarbonizing the iron and deoxidizing the metal by combining the carbon of the iron with the oxygen in the bath, burning the evolved carbonous oxide gas and heating the charge thereby.*

## GERMANY

Kl. 10a. Nr. 141,451, July 31, 1901. INVENTION FOR THE WETTING AND TRANSPORTING OF COKE. — Wellman Seaver Engineering Co., Cleve-



land (V. St. A.) The coke is pushed out from the chamber *a* into a trough *b*. Here it is wet and loaded into the car *c*. The trough *b* is moved by means of a movable crane *d* before the battery of ovens, and also from and to the ovens by the frame upon the movable part *e*. To lessen the oscillation, the forward end of the trough is suspended by an eye to a solid frame *f*, which is firmly fastened to the movable part *e*. Its rear end is fastened by a chain *g*, which is given a positive motion by the telescoping tube.
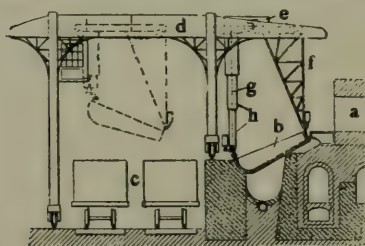
Kl. 31a. Nr. 143,143, November 7, 1901. Draught in Tilting Crucible Smelting Furnace. — Badische Maschinenfabrik und Eisengiesserei, vorm. Sebold und Sebold & Neff in Durlach. The tube *a* where the blast enters is connected hermetically with the stationary tube *b*, which carries the blast, during the working of the furnace, in such a way that the conical end of the tube *c* fits into a corresponding mouthpiece of *a*, and forms with it a closed conductor for the air; while by the tilting of the furnace, the entrance tube for the blast *a* cuts off the stationary conducting tube *b*, without it being necessary to lift the crucible.
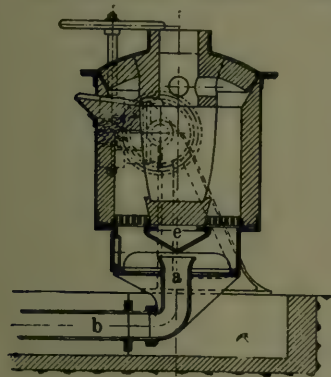
Kl. 49f. Nr. 142,174, November 5, 1901. Device for the Manufacture of Hollow Bodies. — Gustav Gleichmann in Düsseldorf. The device has in view the manufacture of hollow bodies by punching and stretching of solid pieces of metal, whereby they receive a considerably greater length than in the beginning. The piece of metal *b* is first inserted in a matrix *a* provided with wavy grooves, while it is held firmly by a collar *c*. By means of force the piece of metal is pressed into the unevennesses of the matrix and held fast, and the complete perforating of the piece of metal by means of a spike *e* then follows. The unevennesses may be then drawn or rolled out.
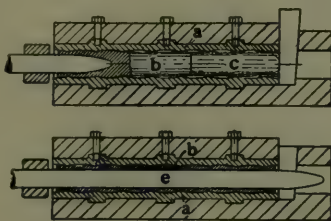
Kl. 7c. Nr. 142,824, March 21, 1902. Machine for Bending Sheet Metal Provided with Four Bending Rollers. — Maschinenfabrik Weingarten, vorm. Heinrich Schatz a. G. in Weingarten (Wurtt.). In order to operate the two rollers ordinarily required for the curving of tubes, etc., by one lever, *a*, one of the four rollers, *a, b, c, d,* is placed in a position where it cannot be displaced; *b*, which is adjustable, is placed perpendicularly under it; *d* is placed behind in the shield *f*, which turns about the movable curved roller *c* as a pivot. Through a lifting of the roller *c* there takes place immediately a guided movement of the roller *d*.
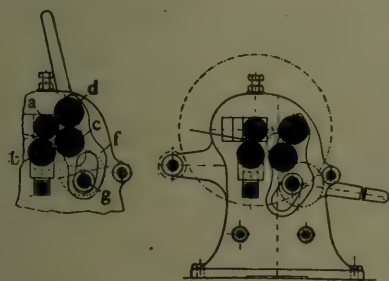
Kl. 7a. Nr. 142,653, Dec. 7, 1901. ROLLING MILL FOR THE ROLLING OF TUBES AND OTHER HOLLOW BODIES. — Otto Heer in Düsseldorf. The novelty of this rolling mill is that the piece of metal is brought back after every passage through the rollers *a* and *b* through the same path by moving it in a direction opposite to that in which it was pushed forward. After it comes out from the pass it is brought by a simple lengthwise or sidewise shifting to a wider working point. Behind the grooving rollers *a* and *b* are also placed two grooved rollers *c* and *d*, the upper fixed, the under movable. It is so raised by a spring *h*, that the piece of metal as it comes out is pressed against the upper roller. The latter is forced constantly in the opposite direction, by means of the toothed wheels, *e*, *f*. The piece of metal issuing from the rollers *a* and *b* is pressed so hard against the upper roller *c* by means of the rolled *d*, which of itself has no impulsion, that it is pushed back from this through the rollers *a* and *b*, which at this moment are lifted so far that the piece of metal can work through freely.
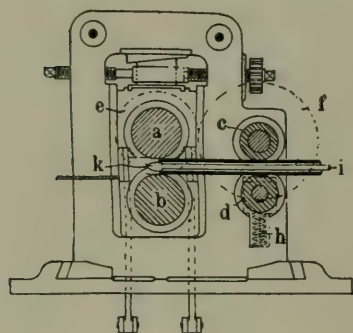
Kl. 49e. Nr. 143,070, June 22, 1902. DEVICE FOR EASILY TIGHTENING AND FREEING THE MATRIX IN HYDRAULIC PRESSES. — Fried Krupp, Grusonwerk in Magdeburg, Buchan. An hydraulic auxiliary piston *k* presses the movable press chamber *f* while the pressure is upon the stationary matrix *e* and after the blow draws back again.

Kl. 31c. Nr. 143,456, October 9, 1902. DEVICE FOR THE MANUFACTURE OF POROUS YET SOLID SAND-MOLDS OF CORES. — F. Kindling in Halle a. S. Trocha. For the manufacture of porous molds and cores, sand is mixed with coal ashes in the ratio of 1.3 for molds, and 1.1 for cores.
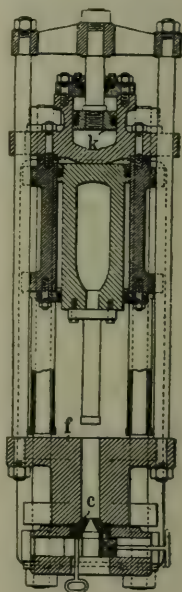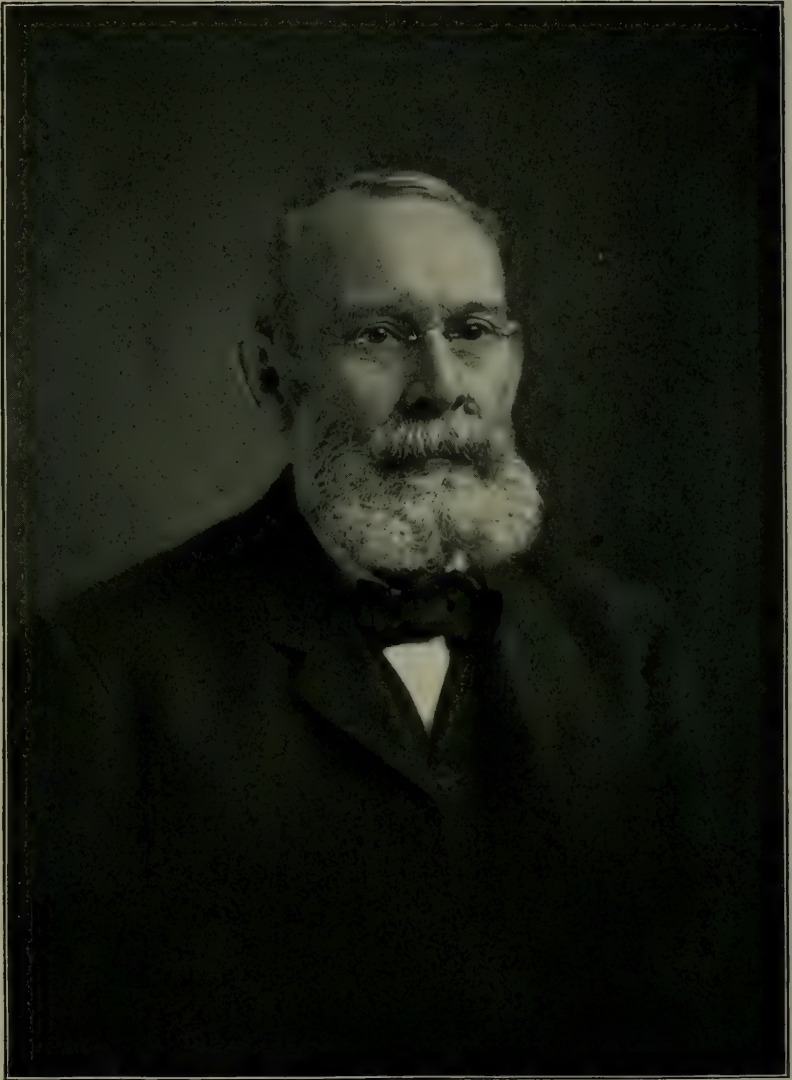
CHARLES B. DUDLEY

## NEW AUTOGRAPHIC METHOD TO ASCERTAIN THE CRITICAL POINTS OF STEEL AND STEEL ALLOYS*

### By E. SALADIN

Chief Engineer, Metallurgical Department, Schneider & Company, Le Creusot, France

THE classical methods employed to detect the critical points both on heating and cooling are well known. They are too important not to be frequently used in metallurgical laboratories; but, precisely because of their importance, it is to be regretted that they are so long, and call for such delicate manipulations.

Mr. Osmond places the thermo-electric couple of a Le Chatelier's pyrometer between two pieces of the steel under treatment. These pieces are heated slowly and then allowed to cool, in a single or double crucible. By means of a paper band (delivered by a Morse instrument, for instance) the time required for the index of the galvanometer to pass from one division to the next one is noted. A curve is then constructed of which the abscissæ correspond to the temperature scale and the ordinates to the successive times occupied in passing over each division.

Omitting the systematic error of the couples, which does not give on the galvanometer scales deviations exactly proportional to the temperatures $\theta$, the curve obtained in this way is very nearly that represented by the functions $y = \dfrac{dt}{d\theta}$, $y$ being the ordi-

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nate, $\theta$ the abscissa, and $t$ the time, this being true for any value of $\theta = f\ (t)$; but which in practice it is endeavored to make regular.

This method is evidently a very delicate one, since if the division of the scale were infinitely small, an asymptote to the curve should correspond to the slightest stop caused by an evolution or absorption of internal heat. Unfortunately each such experiment requires much time; it is difficult to record with great accuracy the passage of the needle over one hundred or so divisions of the scale; the construction of the curve is laborious, and one hesitates to repeat frequently these experiments in spite of the accuracy of the results.

Roberts-Austen published in *The Metallographist* for July, 1899, a modification of Osmond's system, which is as follows: Together with the steel to be examined a piece of platinum or of porcelain is subjected to the same heat treatment. One thermoelectric couple gives by means of a galvanometer the temperature of the piece of steel, while a second couple placed in the piece of platinum and connected in opposition with the first indicates on a second galvanometer the difference of temperature between the platinum and the steel.

The beam of light reflected by both galvanometers is received on a sensitive plate which moves proportionately to the time. Two curves are thus obtained, one representing the variation of the temperature of the steel in function of the time, and the other the variation in the difference of temperature between the steel and the platinum, also in function of the time.

These two curves give the factors needed and permit one, through a graphical construction, to ascertain the position of the critical points. This method requires a rather delicate mechanism to impart the proper motion to the photographic plate; it also requires some calculation or drawing; but it possesses the great advantage of correcting the small errors due to air currents and other causes, which frequently interfere with the regularity of the heating or cooling in Osmond's arrangement, because these causes of irregularity act upon both the steel and the platinum.

In these two classical methods time intervenes as a variable. Is not the difficulty of their application due to this intervention? Examining Roberts-Austen's apparatus it is seen that two variables are considered: the temperature of the steel and the difference

of temperature between the steel and the platinum, which would yield a very sharp curve of the phenomenon if the apparatus was made to register a curve having the temperature as abscissæ and the difference of temperatures as ordinates. This is what I have succeeded in doing in the method now to be described.

The problem which had to be solved thus to modify the method of Roberts-Austen consisted in so placing the galvanometers as to cause the luminous beam reflected by one mirror to be deflected horizontally, while the beam reflected by the other mirror is reflected vertically. It is an application of the principle of Lissajoux.

Such disposition has already been used, especially in the case of a mirror supported by three points placed at the apex of a rectangular triangle, but the application of this method to galvanometers was very delicate and difficult.

I decided to receive the beams of light on the mirrors of two galvanometers, one having a vertical axis of rotation and the other an horizontal axis, the mirrors being placed at the conjugate foci of a lens.

Any light proceeding from one of the mirrors is in this way evidently received by the other mirror and the desired combination of the two oscillations is obtained. Mr. Pellin, a manufacturer of instruments of precision, advised me to retain the vertical axis of the galvanometer and to transform by means of a prism the plane of oscillation of the beam of light. This horizontal plane may readily be transformed into a vertical plane by causing the beam to pass through a totally reflecting, rectangular prism. By means of this prism the disposition of the instruments became very simple and this method was adopted.

Following the travel of the luminous beams (in Fig. 1) the various parts are as follows:

1. A source of light sending a parallel beam of light upon the mirror of the galvanometer, recording the difference of temperatures.

2. A sensitive galvanometer with a mirror reflecting the light at an angle of 90° in a horizontal plane.

3. A totally reflecting prism transforming the horizontal oscillation into vertical oscillations.

4. Lens at the conjugate foci of which are placed the mirrors of the two galvanometers.
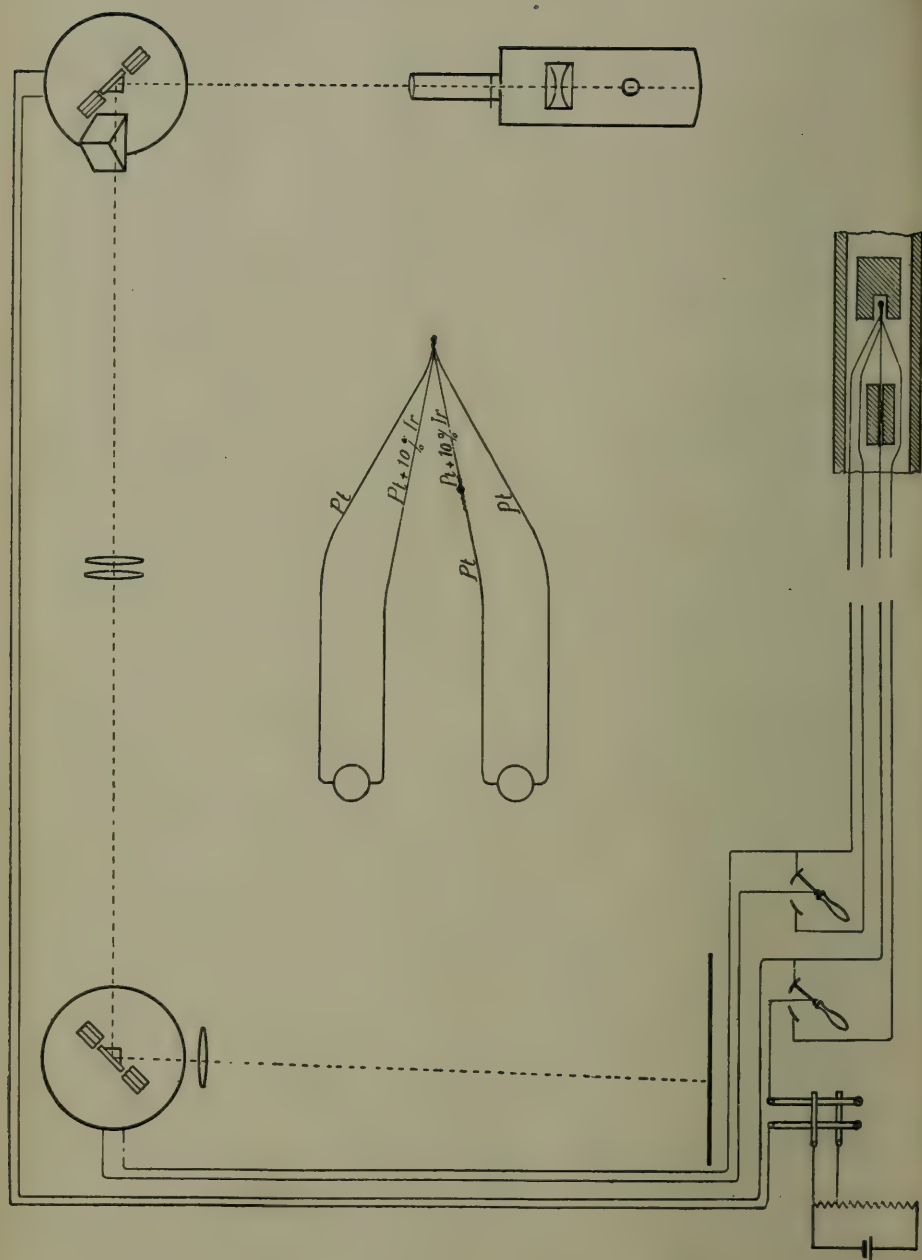
Fig. 1.

5. Galvanometer recording the temperatures, with mirror reflecting the light at an angle of 90° in the horizontal plane.

6. Objective receiving the beam of light and condensing it upon a screen. This objective may be placed before or after the galvanometer, but in every case very near the mirror.

7. Ground glass screen to follow the phenomenon or photographic plate to photograph it.

The accompanying illustration (Fig. 2) shows the arrangement of the various parts. On the right is an electric furnace of Heræus for the treatment of the specimens. In order to photograph them the instruments were placed on a table, in a bright light, while in reality they are arranged in a brick foundation and in a dark room.

The source of light consists of an acetylene lamp or an incandescent lamp, the light of which is thrown by a condenser upon a diaphragm. The latter has an opening with two threads at right angles for adjustment or a very small hole for photographing the light. Through a suitable mechanism both these apertures may be used at will. In front of the diaphragm an objective is so placed that the light is converted into a parallel beam.

Desprez-Darsonval galvanometers are used, in which the ordinary mirrors are replaced by a small totally reflecting prism measuring about 100 millimeters in height, the sides of the prism being parallel to the vertical axis of suspension. The plane silvered mirrors do not yield as sharp images and if they be externally silvered it is difficult to keep them bright.

The sensitive galvanometer used gives on the screen a vertical deviation of five or six mm. for each degree centigrade of the couple; while an ordinary galvanometer gives a deviation of about 15 mm. for each 100° between 400° and 900°.

The tension of the threads is such that the moveable solenoids make about 25 double oscillations per minute, in open circuit.

By following with a small screen the motion of the beam of light the various lenses are readily adjusted so as to obtain a sharp image. If desired, the times may be recorded by interrupting periodically the luminous beam by means of a screen moving by clock work.

As a standard metal we use instead of platinum, steel containing 25 per cent of nickel. As the critical point of this steel

is below 0°, it is well adapted for these experiments.    At the
beginning of each experiment, two axes are traced on the photo-
graphic plate by a slight deviation of the galvanometer mirrors,
and this can readily be produced by sending through them suc-
cessively two currents of equal intensity, but of opposite direc-
tion, using a commutator for this purpose.    Mr. Pellin recently
constructed for Mr. Le Chatelier a modification of this arrange-
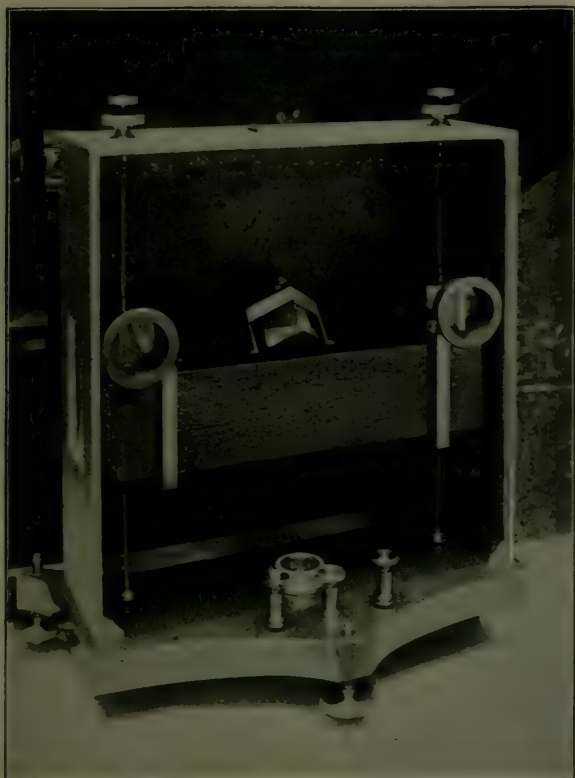


Fig. 3.

ment.    His apparatus is very simple and much condensed; by
placing the galvanometers much nearer together, the lens could
be omitted.    The luminous beam from the source of light passes
first through a lens, is received by the silvered mirror of the first
galvanometer, passes through a totally reflecting prism, reaches
the mirror of the second galvanometer, passes through a second

lens and reaches the screen or photographic plate. With this arrangement it is possible to place all the instruments in a metallic box closed by a glass side carrying the two lenses. The movable frames of the Desprez-Darsonval galvanometers are placed between two rectangular magnets. If the mirrors are sufficiently large, the luminous beams do not fall outside.

The accompanying photograph (Fig. 3), which I owe to the kindness of Mr. Guillet, shows this instrument recently installed in the laboratory of which he has the management at the works of Messrs. de Dion & Bouton at Puteaux.

## APPLICATIONS

The possible applications of this outfit are very numerous, for it makes it possible to record all the phenomena which may be represented by a function of two variables, provided these two variables may be represented by the proportional rotation of a mirror, in the many instances when the mirrors must turn around two parallel axes.

The method is especially applicable in the case of two variables, which can be represented by a proportional electro-motive force as is the case with a temperature observed by means of a thermoelectric couple or with a distance traveled along the thread of a potentiometer, etc., etc., the rotation of the mirrors being obtained by means of a galvanometer. Other combinations may be conceived capable of useful application in industrial laboratories.

Confining ourselves to the determination of the critical points of steels and its alloys, we give below some photographic reproductions of our results:

The first series (Fig. 4) represents carbon steels containing from 0.06 to 0.66 per cent of carbon. The curves were obtained in ten minutes by heating in a double crucible, according to Osmond. It will be seen that the percentage of carbon in the steel may be easily inferred from the appearance of the curves.

A second series (Fig. 5) represents two carbon steels. They were heated in an electrical furnace. The heating lasted one hour, and the cooling the same length of time.

A third series represents nickel steels. The lowering of the critical point as the nickel content increases is clearly seen (Fig. 6).

Recalescence Curves

C = 0,06
Mn = 0,31

C = 0,10
Mn = 0,31

C = 0,15
Mn = 0,54

C = 0,22
Mn = 0,53

C = 0,36
Mn = 0,52

C = 0,48
Mn = 0,45

C = 0,66
Mn = 0,71

Cooling Curves     Fig. 4.     Heating Curves

C $= 0.36$ %
Mn $= 0.42$ %

C $= 0.46$ %
Mn $= 0.63$ %

1100  1000  900  800  700  600  500  400  300  200  100  0
Temperatures

Fig. 5.  Carbon Steels.



C $= 0.32$ %
Ni $= 3.04$ %
Cr $= 0.10$ %

C $= 0.40$ %
Ni $= 2.74$ %
Cr $= 0.58$ %

C $= 0.28$ %
Ni $= 11.59$ %
Cr $= 0.64$ %
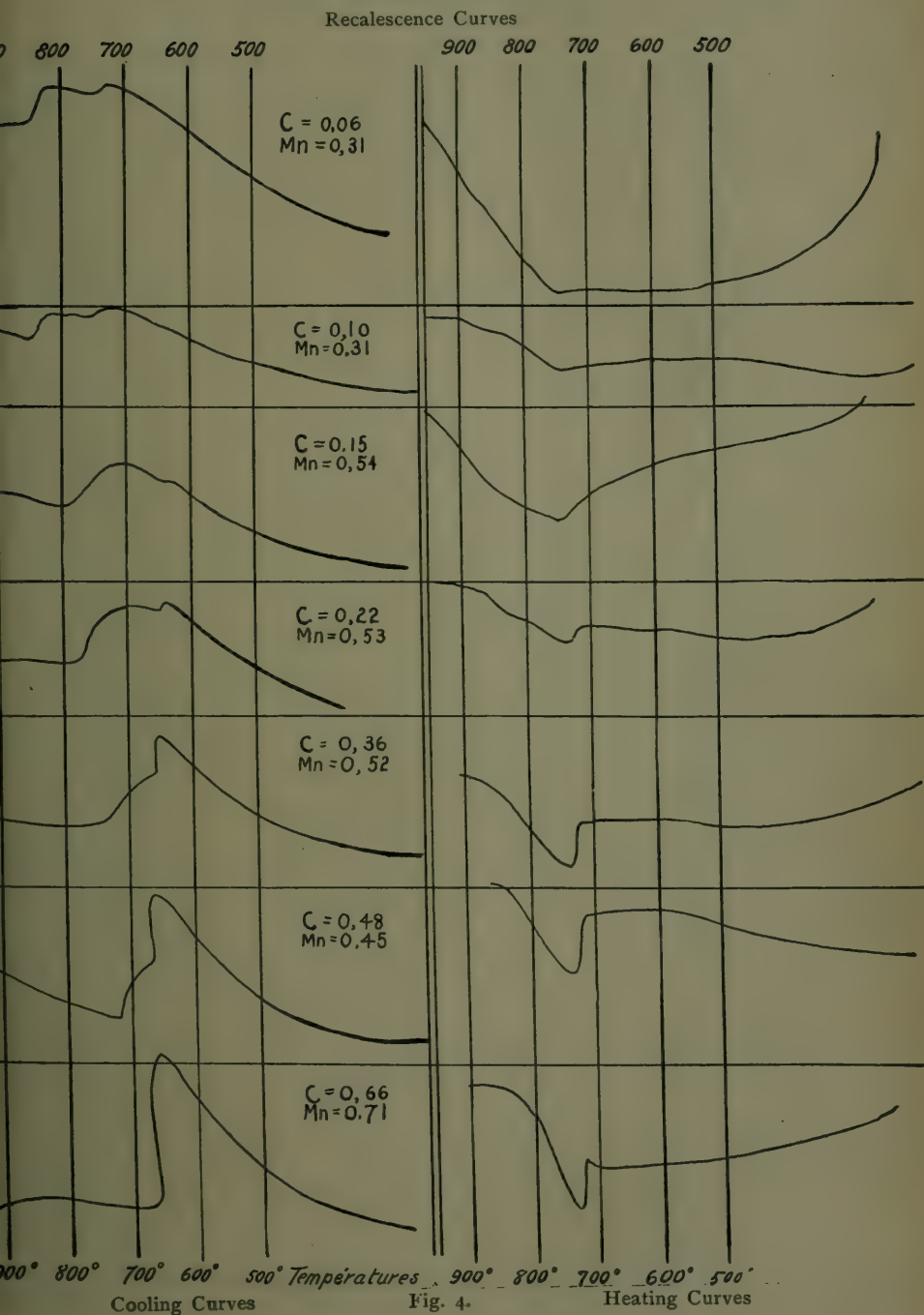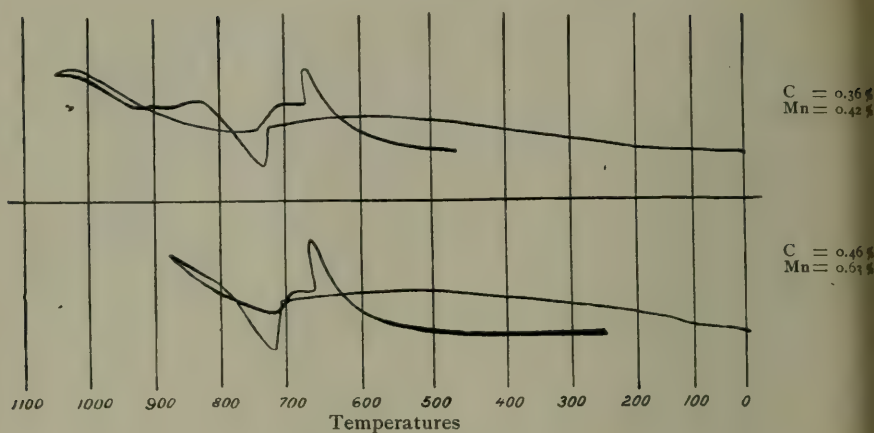
1100  1000  900  800  700  600  500  400  300  200  100  0
Temperatures
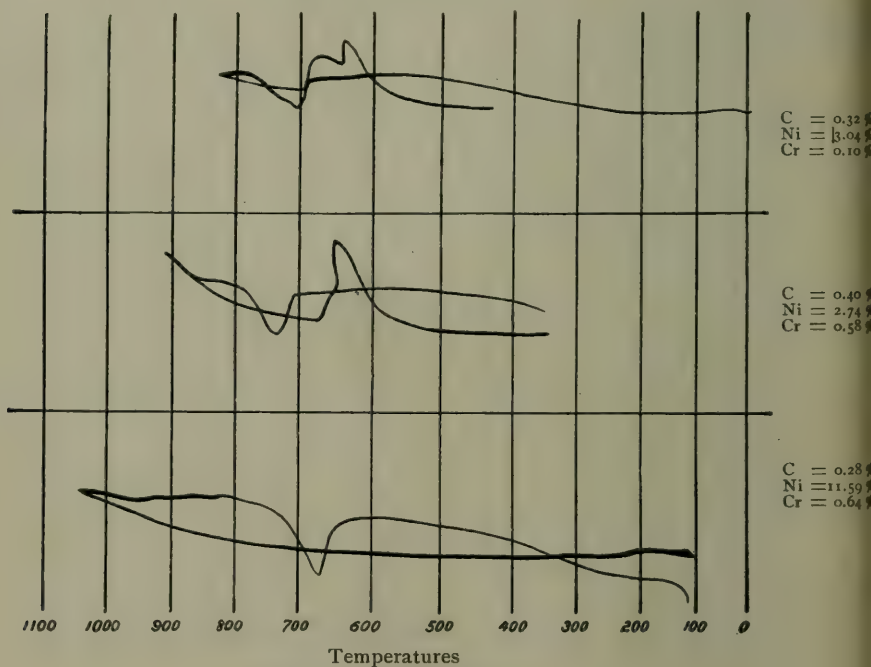
Fig. 6.  Nickel Steels.

A fourth series, obtained with manganese steel, leads to the same conclusions as the nickel-steel series (Fig. 7).

The fifth series shows the critical point of a steel containing one per cent of titanium.  The position of the critical point is

C = 0.31 %
Mn = 1.66 %

C = 0.14 %
Mn = 6.50 %

C = 0.20 %
Mn = 8.75 %

C = 0.65 %
Mn = 5.60 %

C = 0.90 %
Mn = 4.16 %

C = 1.66 %
Mn = 13.80 %

1000   900   800   700   600   500   400   300   200   100   0

Temperatures

Fig. 7.   Manganese Steels.

C  = 0.73 %
Ti = 0.97 %
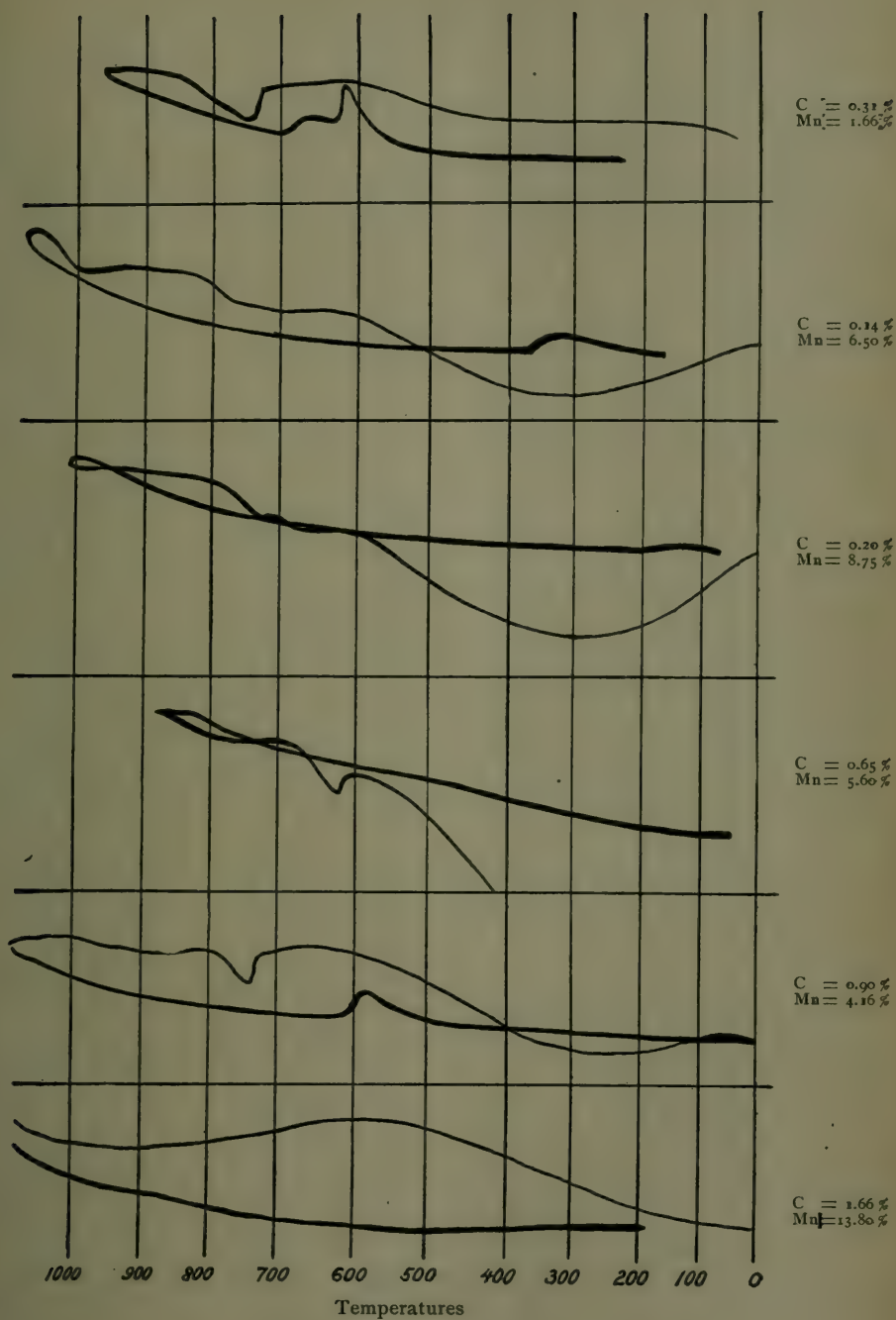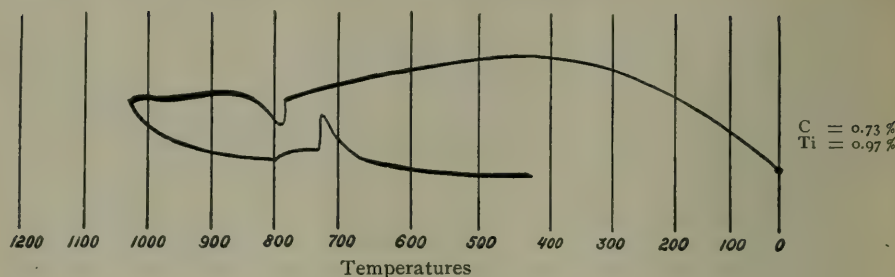
Temperatures
Fig. 8.  Titanium Steel.

raised, and this agrees with Roberts-Austen's theory.  Between the curves of the second series and those of the fifth the rise of temperature is about 60° (Fig. 8).



C  = 0.17 %
Mn = 0.26 %
Ni = 2.98 %
Cr = 1.82 %

C  = 0.175 %
Mn = 0.280 %
Ni = 6.00 %
Cr = 0.73 %

C  = 0.317 %
Mn = 0.18 %
Ni = 6.00 %
Cr = 1.39 %
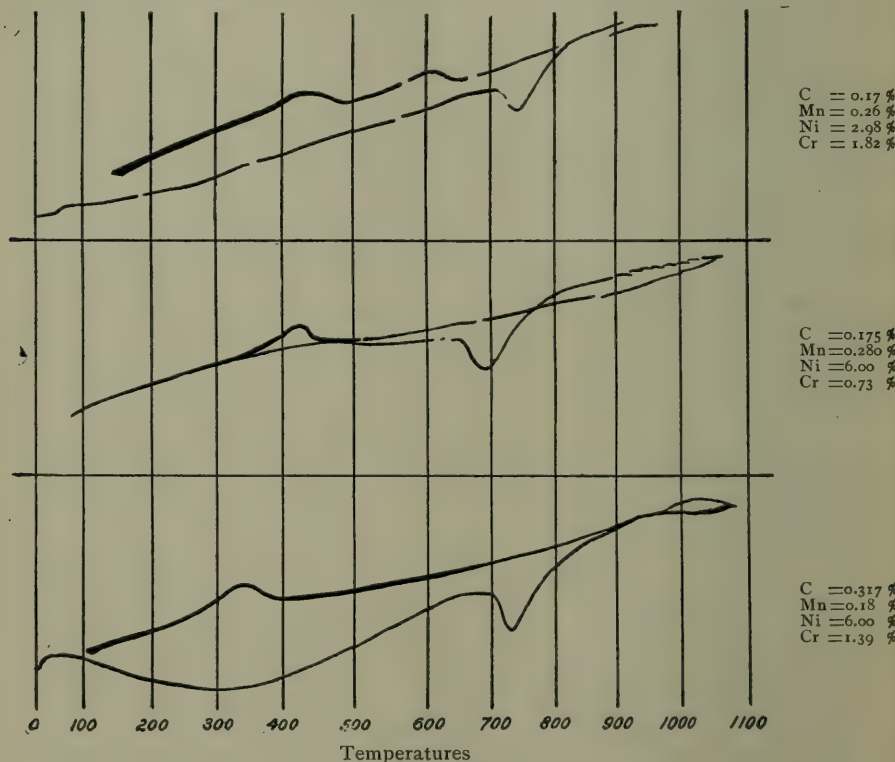
Temperatures
Fig. 9.  Nickel-Chromium Steels.

The sixth series was obtained in ascertaining the critical points of steel containing respectively, nickel and chromium; nickel, chromium and tungsten; chromium and molybdenum;

C = 0.20 %
Mn = 0.18 %
Ni = 4.00 %
Cr = 0.43 %
W = 0.85 %

C = 0.17 %
Mn = traces
Ni = 4.46 %
Cr = 0.42 %
W = 1.76 %

Temperatures
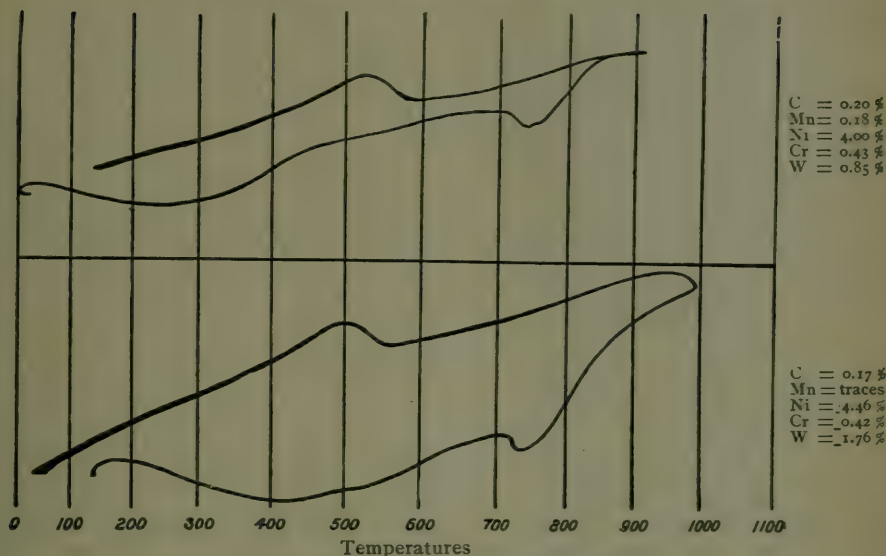
Fig. 10.  Nickel-Chromium-Tungsten Steels.

molybdenum; nickel, chromium and molybdenum; as well as the critical points of cast iron rich in manganese and of spiegeleisen. (Figs. 9-15.)

Finally the seventh series shows the result of an experiment conducted in order to ascertain whether the gap between the posi-



C = 0.11 %
Mn = traces
Cr = 1.48 %
Mo = 1.66 %

C = 0.89 %
Mn = traces
Cr = 1.48 %
Mo = 1.53 %

Temperatures
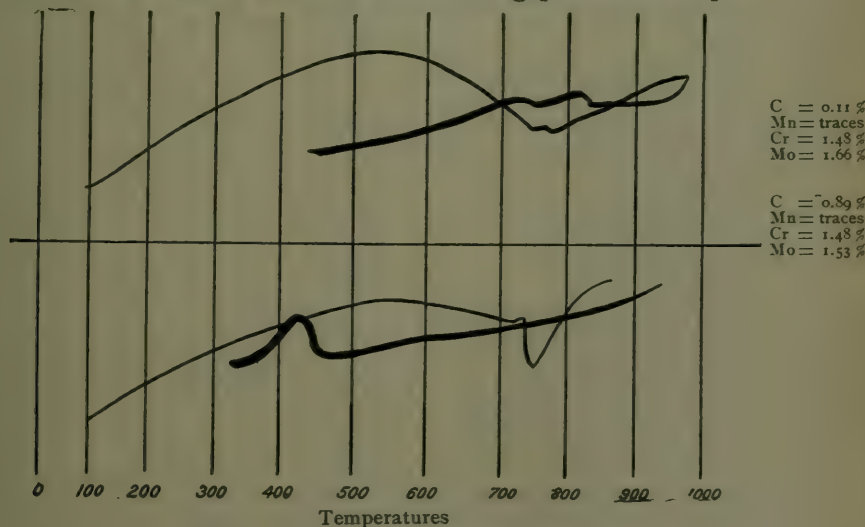
Fig. 11.  Chromium-Molybdenum Steels.

Temperatures
Fig. 12. Molybdenum Steel.

C  = 0.28 %
Mn =traces
Mo = 1.83 %
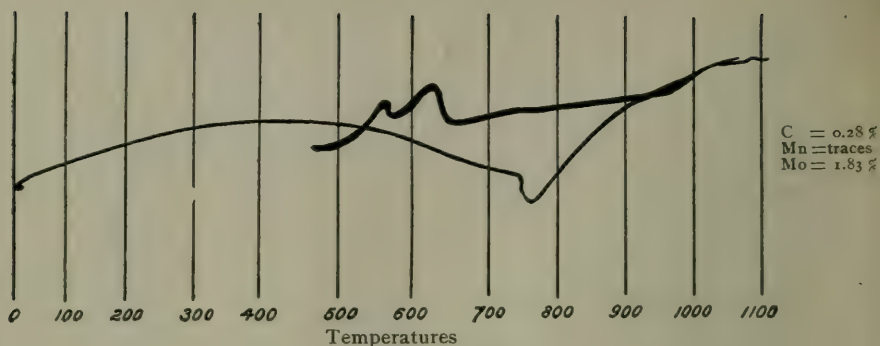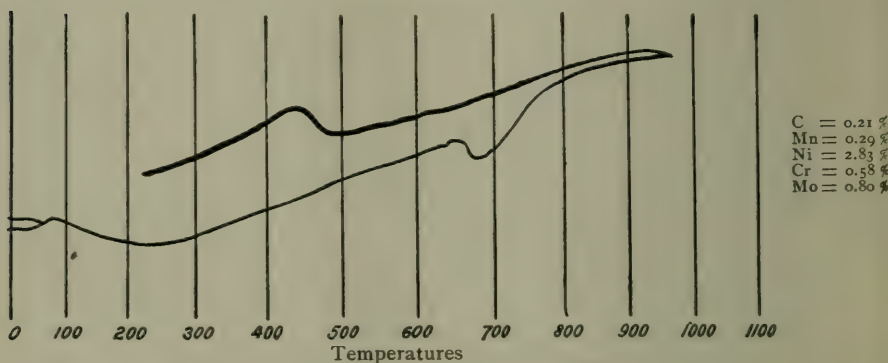


Temperatures
Fig. 13. Nickel-Chromium-Molybdenum Steel.

C  = 0.21 %
Mn = 0.29 %
Ni = 2.83 %
Cr = 0.58 %
Mo = 0.80 %
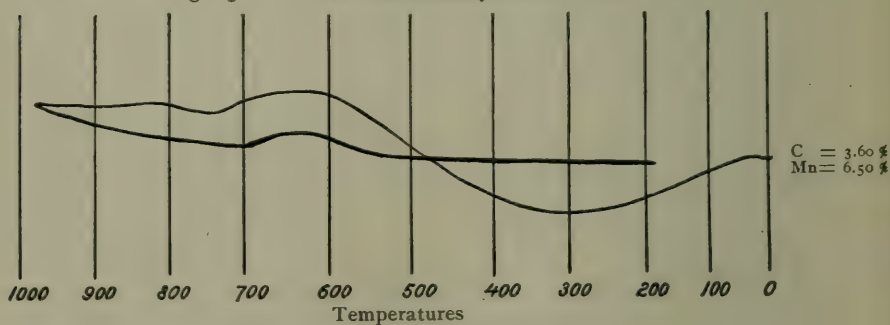


Temperatures
Fig. 14. High Manganese Cast Iron.

C  = 3.60 %
Mn = 6.50 %
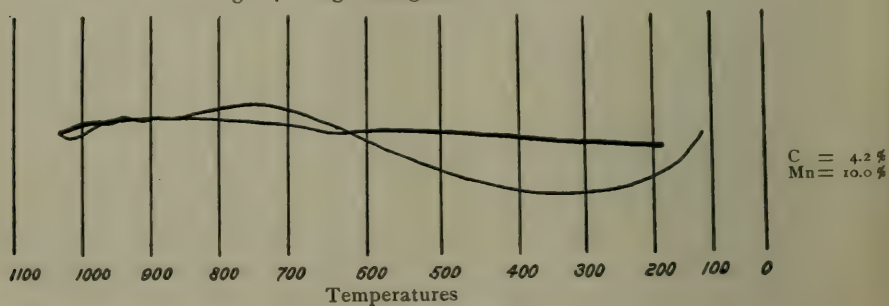


Temperatures
Fig. 15. Spiegeleisen.

C  = 4.2 %
Mn = 10.0 %

tion of the critical point on heating and that on cooling is not due, partly at least, to experimental error. A very refractory mixture of quartz and clay was prepared and divided into two parts. The first was moulded as such to serve as standard, while to the second was added some gold obtained from the precipitation of the chloride by ferrous sulphate. About one gram of gold was added for each gram of refractory material. The mixture was carefully dried, then slightly moistened and made into a ball around one of the thermo-couples. The finely divided gold mixed with this refractory substance corresponded to the constituents of an alloy which undergo a modification at the critical temperature. Each particle of gold should melt at a certain constant temperature, and solidify at this same temperature, so that the critical points of this mixture should be found at the same temperature on cooling and heating, if the method is free from experimental error (Fig. 16).



| 1200 | 1100 | 1000 | 900 | 800 | 700 | 600 | 500 | 400 | 300 | 200 | 100 | 0 |

Temperatures
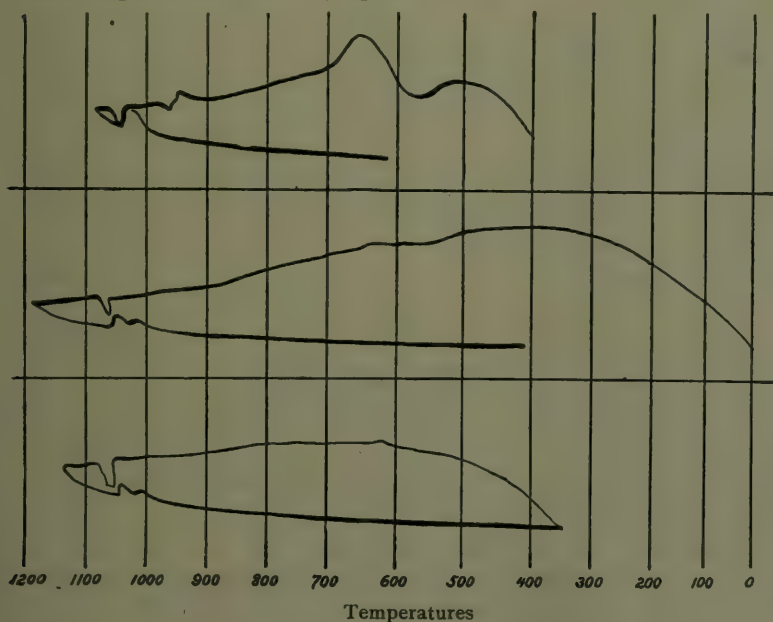
Fig. 16. Melting-point of Gold.

This was confirmed by the experiment, a difference of 10° only having been found between the two points. The three curves reproduced here were obtained successively with the same sam-

ples heated in an electrical furnace; they exhibit a perfectly constant position for this critical point which is the melting point of pure gold. This method may be used for the graduation of couples. The same experiments illustrate also the phenomena of absorption and evolution of heat characteristic of the baking of clay and quartz. The evolution of heat by the clay at about 650° is not complete at the first heating (which lasted one hour, followed by a cooling period of one hour and 45 minutes), as it is still found during the third heating.

By means of this apparatus we also studied the thermal phenomena which accompany the hardening operation. In this case, the curve is registered in a few seconds and a powerful source of light, such as an electric arc, is required.

To sum up, this method makes it possible to study slow or rapid phenomena, the results being free from any personal error. It requires but a short time. Using an electric furnace, for instance, the heating speed of which is previously known, it suffices to turn on the current, to heat for a certain length of time (say one hour), and to develop the plate after the furnace has cooled for another length of time (one hour and 30 minutes, for instance).

These instruments have been placed on a solid brick foundation, thus always retaining their proper position, and the whole enclosed in a dark room.

The results recorded here were obtained in the laboratory of Messrs. Schneider & Company, Le Creusot, France, under the direction of Mr. Cohade, and with the valuable assistance of Mr. Lucas.

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## ON FRAGMENTS OF CAST IRON, DESIGNATED AS CRYSTALS

### By CARL BENEDICKS

IN the January, 1903, issue of *The Metallographist*, J. E. Johnson, Jr., gives a description of " Some Unusual Crystals of Cast Iron."

Prof. H. M. Howe, in a postscript to the above article, expresses his opinion that the specimens in question are not crystals of iron, " but that the iron simply cleaves along the plates

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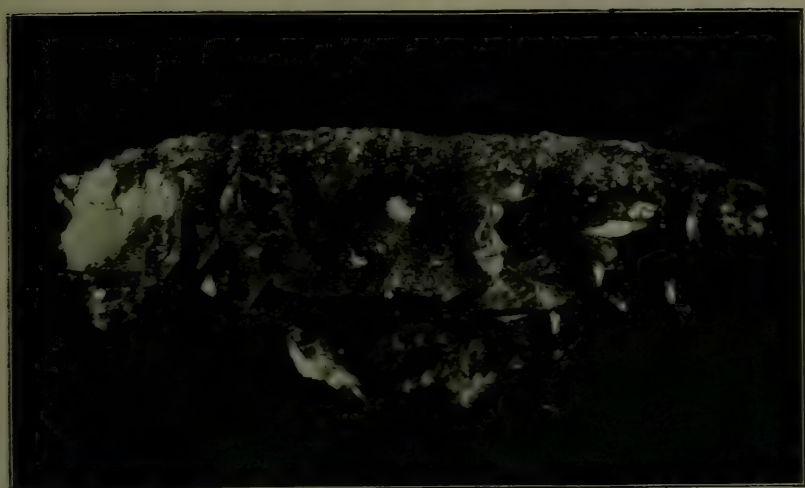
Fig. 1. Natural Size.

of graphite, and that the form of the fragments is simply due to the shape of the graphite plates."

This opinion, however, for which no definitive evidence is given, does not exclude the possibility of the graphite plates being themselves crystallographically orientated, thus possibly giving to the fragments a true crystallographical character.

Having made some crystallographical measurements on this kind of iron — independently of the above notes — I will quote the result, which seems to give a satisfactory answer to this question.
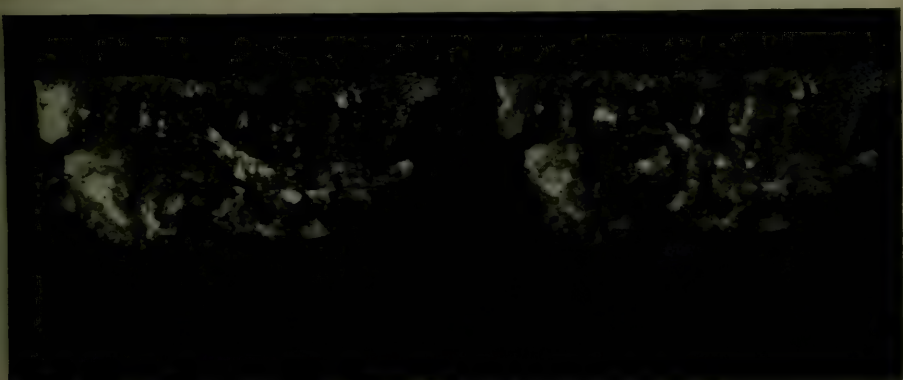


Fig. 2. One-half Natural Size.

The mode of occurrence of the specimens studied by me is quite the same as that described by Mr. Johnson; the blast-furnace was, however, a charcoal one (Gysinge, Sweden). It is to be noted, that such " crystallized " iron is by no means rare, being always found at the bottom of a blast-furnace which has been running for a sufficient time. Here it is often called " graphite iron," a name that I adopt in the following.
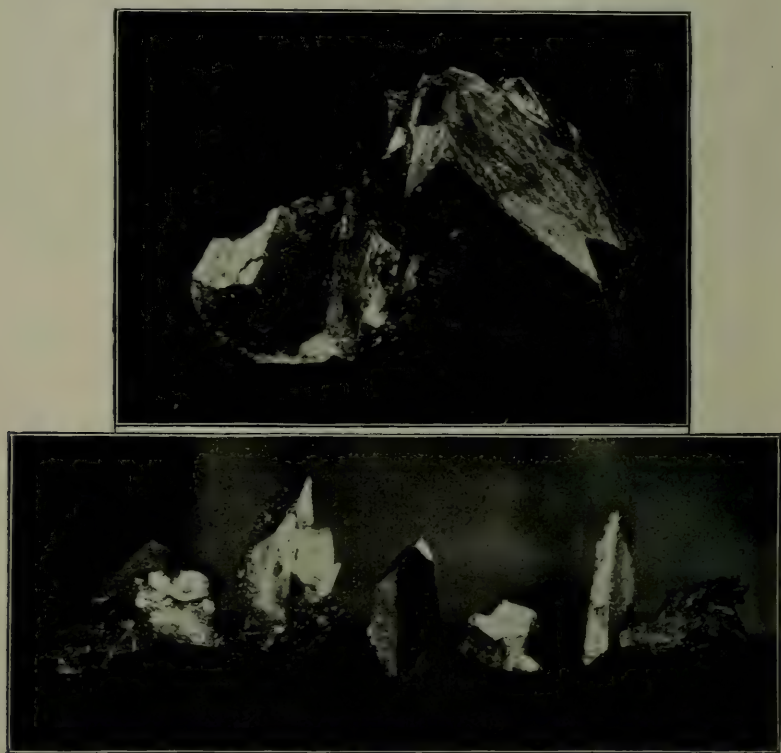


Fig. 3.   Natural Size.

The general appearance is shown by the photograph (Fig. 1). As Mr. Johnson justly remarks, a photograph, even a beautiful and clear one, gives no sufficient idea of the specimens; but the combination of two stereoscopic images (Fig. 2) gives a very substantiate reproduction of the form and lustre of a typical specimen.

For people not familiar with observing stereophotographs

without a stereoscope, it is to be recommended that they hold a piece of dark paper between the eyes, thus preventing the right eye from seeing the left image, and vice versa.

In the lower part (Fig. 2), one sees a piece of the hearth bottom, impregnated with small iron spots. Upon this mass comes the graphite iron of a coarse, crystallized appearance, and in the upper part, one distinguishes a thin layer of fine-grained pig iron. When the furnace is blown out there will always remain some molten iron on the lower parts of the bottom; this iron, solidifying relatively quickly, gives the fine-grained layer.

The graphitic iron, as pointed out by Professor Howe, cleaves along the plates of graphite; in this way one easily gets fragments, which are very like true crystals (Fig. 3).

I have subjected about 20 such fragments to crystallographical measurements by means of a reflexion goniometer. By rubbing the surface with a piece of wood, one gets them sufficiently reflecting.

Although the fragments to a great extent had the same shape, the corresponding angles varied considerably. The result
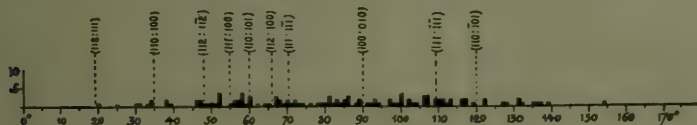


Fig. 4.

of the measurements (about 120) is given in the diagram (Fig. 4). The measured angles are, for each degree, given horizontally and the number of identical angles vertically.

The diagram shows that no marked maxima occur in the frequency of the angle values, or in other words, that *the cleavage plates of graphite are not crystallographically orientated in certain main directions.*

The measurements, it is true, are not evenly spread over the whole range, but the existing, insignificant maxima — which would probably to a great extent disappear, if the number of measurements was still greater — do not, or at least very badly, correspond to the angles of the main crystal forms of the regular system. A certain number of these are indicated in the Diagram, as for instance; the octahedron angle 70″ 31′ (111:111), etc. In

fact, it must be considered as well established, specially through the researches of Osmond & Cartaud,* that iron crystallizes in the regular system.

As to the metallography of graphite iron, this is in full harmony with the above result. Without further discussion, I reproduce some typical photographs.

Fig. 5 (surface only polished, magnification 70 diameters)



Fig. 5.  Magnified 70 Diameters.		Fig. 6.  Magnified 1100 Diameters.
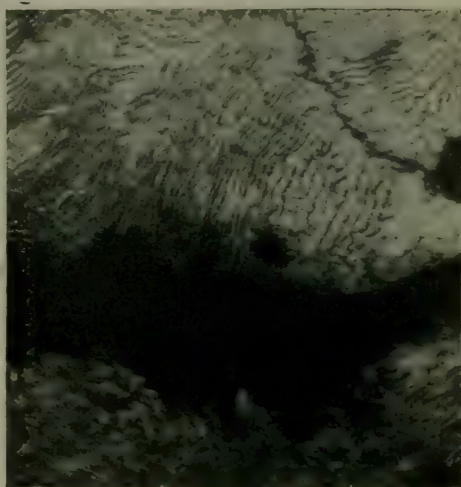
shows in the upper part the well-known small graphite plates of gray pig iron. In the lower part one distinguishes a much larger graphite plate, along which the iron easily cleaves. It ought to be observed that the different graphite plates almost never come into contact with each other; this indicates that they are made up and enlarged in the solid metal, — graphite particles in the neighborhood of a greater plate are assimilated by this. In this respect there seems to be a very marked difference between graphite iron and spiegeleisen, which Professor Howe, indeed, quite justly parallelizes. The cementite plates, along which spiegeleisen cleaves, are crystallized from a fluid mass; in this case, there is *a priori* absolutely no probability for the cleavage fragments being of crystallographic nature, in the case of graphite iron it is *a priori*

* *The Metallographist,* IV, 1901, p. 119.

impossible to decide, if the cleavage plates would not be orientated in the mass of the solid iron.

Under high magnification one observes the well-known pearlite structure, which characterized a normal gray pig iron. Fig. 6 shows, at a magnification of 1,100 diameters, such pearlite, surrounding two graphite fields.

Fig. 7 (etched as the former, with iodine) shows at a magnifi-



Fig. 7. Magnified 1,500 Diameters.

cation of 1,500 diameters, the appearance of some white spots, occurring sparingly in graphite iron; apparently it consists of white pig iron, not yet transformed into gray.

To sum up: There can be no possible doubt, according to the view of Professor Howe and contrary to the opinion of Mr. Johnson, that the fragments of graphite iron are not crystals of iron, the graphite plates, along which iron cleaves, having no crystallographic orientation.

# NOTES ON THE STRUCTURE OF AN ALLOY, WHICH ON FREEZING, SEPARATES INTO SOLID SOLUTIONS AND A EUTECTIC *

By J. E. STEAD

Middlesborough, England

SIR WILLIAM ROBERTS-AUSTEN, in his "James Forest" lecture, delivered before the Institution of Civil Engineers, 23d April, 1902, reproduced a series of photographs
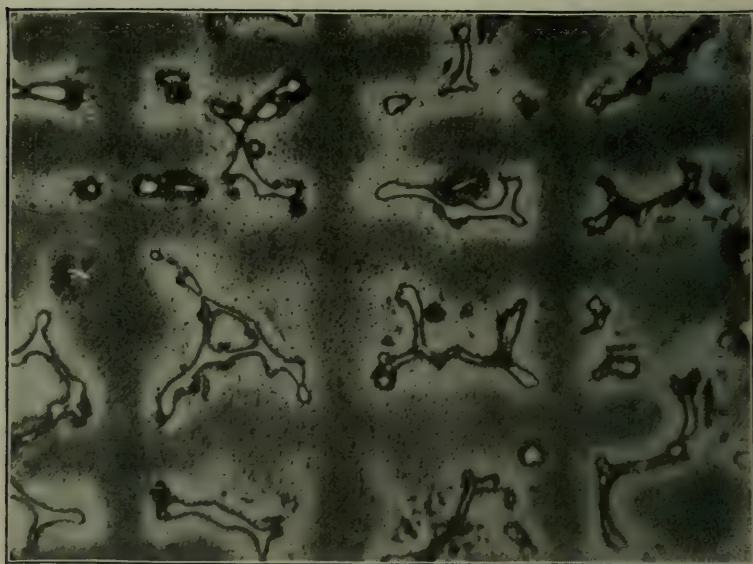


by the writer, illustrating the structure of the phosphorus and iron compounds.

One photograph in the series represented the structure of a metal containing a little more than two per cent phosphorus, and not more than traces of carbon, manganese, etc., and about 97.8 per cent iron. It had been melted in a magnesia-lined crucible and allowed to solidify therein. The original photograph was so much reduced in reproduction, it is difficult to see how perfect an illustration it is of what occurs when an alloy of

* Received October 22, 1903.

two components, which form solid solutions and a eutectic, pass from the liquid to the solid state. As it is such an excellent example of what Professor Howe in his work on " Iron, Steel and other Alloys," describes as a " land-locked " type of deposition, I venture to reproduce here the original photograph with the following brief description:

The dark octahedral spines represent the unsaturated portions which first solidified, which merge into the saturated or white parts surrounding the " land-locked '" eutectic itself.

The researches of Tschernoff were the first to show us, how, when steel or iron freezes, it forms octahedral skeletons of the fir-tree type; that as the stem grows forward branches shoot out at right angles in two directions at right angles to each other, and that from these at the same angle other branches grow. These all develop in thickness as well as in length until the whole mass is solid.

The third series of shoots being in the same direction as that of the parent stem it is easy to understand how, if any eutectic substance were present, it would be eventually " land-locked " between the growing branches.

The photograph of the iron phosphide alloy most clearly shows that this actually occurs. Probably the dark spines consist of the second and third set of branches and not the primary stem.

Although the eutectic imprisoned does not assume the cubical form shown in Professor Howe's most instructive hypothetical diagram, there are similar cubical envelopments and the same gradations from the weak solid solutions in the center of the spines or branches to the saturated solutions when the eutetic is approached.

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## CHARLES B. DUDLEY

CHARLES B. DUDLEY was born at Oxford, Chenango County, New York, July 14th, 1842, of New England parentage, the father being from New Hampshire, and the mother from Connecticut. The movement of the parents from New England to New York State was a part of that general trend of New England blood toward the setting sun, which so markedly characterized the early part and middle of the last century, and

took place at the time when it was going "out west," to go into York State. Dr. Dudley's early years were spent in attending the village school, and later the academy, in the fall and winter, and in working on a farm in summer. In 1862 he enlisted as a private soldier in the 114th New York Volunteers, and spent the greater part of the next three years in the war of the Rebellion. He was in seven battles, participating in the siege of Port Hudson in 1863, in the Red River Campaign in the spring of 1864, and was finally severely wounded in the battle of Opequan Creek, just east of Winchester, in the Shenandoah Valley, on September 19, 1864. The studious habits which may be said to have characterized Dr. Dudley's whole life, manifested themselves even during his army service. During one winter, while the army was in winter quarters at Franklin, Louisiana, he had his Latin grammar and reader sent to him, and devoted many hours of his camp leisure that winter to a study of that language. The books which would now be a valuable souvenir, were ultimately lost, owing to the capture of a lot of stored baggage by the enemy.

Returning from the war in 1865, he began to prepare for college at Oxford Academy and Collegiate Institute, and entered Yale College in the fall of 1867, graduating as A.B. in the class of '71. The next year was spent in newspaper work in New Haven, obtaining means to prosecute further studies, and to pay off obligations already incurred during the previous four years. Having no independent means of his own, Dr. Dudley obtained quite a portion of the funds needed to secure an education, by working at whatever could be found to be done, both in vacation and during term time. In the fall of 1872 he entered the Sheffield Scientific School of Yale College, and graduated in 1874, with the degree of Ph.D., having spent the two years largely in chemical study. His graduating thesis which was published in full abstract, in the " Proceedings of the American Association for the Advancement of Science," was " On Lithium and a Glass Made with Lithium."

The next college year was spent as assistant to Dr. George F. Barker, Professor of Physics, at the University of Pennsylvania, Philadelphia. During this year some translations of technical papers from the German were made, which were published in the " Franklin Institute Journal." In September, 1875, Dr.

Dudley accepted the position of teacher of the sciences in River-view Military Academy at Poughkeepsie, which position he retained only about a month, as on November 10th of the same year he was invited to accept the position of Chemist of the Pennsylvania Railroad Company at Altoona, which position he still holds.

It will be noted that by far the largest portion of Dr. Dudley's active life has been spent at Altoona. When he began his work there, no railroad had a chemist as a regular employee, although many of them had occasional chemical work done. At that time the whole subject of the relation between scientific knowledge and its practical use by railroads, was in a very chaotic state. There were very few if any specifications. The study of the valuable properties of metals and other materials used in construction may fairly be said to have been in its infancy. Engineers, both civil and mechanical, were largely dependent on the makers of commercial products for their knowledge as to the fitness of these products for the purpose desired; also there was an almost absolute absence of positive knowledge as to whether the thousand and one different articles used by railroads, either in construction or in the supplies that are consumed from day to day, were really what they professed to be. Furthermore the study of materials from the standpoint of the service had only just begun. The study of materials from the standpoint of the maker, that is, how to manufacture a given product successfully, had made much more progress; but whether that product so manufactured would give the best results in actual service, was largely an unknown field. This distinction as to whether a product that can be successfully made from the manufacturing standpoint will give the best results in service, is believed to be a real and a valid one, and one that is far too often overlooked. Finally the question as to whether there is any room in a railroad organization for an employee or employees, who should devote themselves to the study of materials from the standpoint of the consumer, who should investigate methods and practices, both of construction and operation, that happen to be in daily use, with the view of their improvement, and who should keep in touch with the progress of scientific knowledge, with the view of applying to railroad operation, such portions as may be fit, was at that time an entirely unsolved problem. To Mr. Theo. N. Ely, formerly Superintendent of Motive Power, and at present Chief of Motive

Power of the Pennsylvania Railroad Company, is due the credit for the conception and the belief that there was room in a railroad organization for an Experimental Department, devoted to the work outlined above, and the securing of a chemist was one of the steps in the development of his idea.

Of the work done by Dr. Dudley during the little over twenty-eight years of his life in Altoona, perhaps that which has attracted the most widespread public attention was the study of steel rails made in the early eighties. The thought which led to and actuated that study throughout was " What does the actual service of the rails in the track teach us, in regard to the kind or quality of steel that will give best service? " The plan of the investigation consisted in taking from the track about a hundred rails whose history was known, approximately one-half of which had given inferior service and the other half better service, and subject these rails to both physical test and chemical analysis. Microscopic examination of steel had not at that time come into prominence. The results of the study seemed to point very clearly to the conclusion that mild or softer steel gave not only a safer rail, but also one that suffered less loss of metal by wear than harder steel. The results were so contrary to the commonly received views on the subject, and were so antagonistic to the interests of the rail manufacturers, since harder steel rails are easier made, that they were received with incredulity. The studies were published in a series of papers in the " Proceedings of the American Institute of Mining Engineers," and led to a most animated discussion. They were also published either in full or in copious abstract in various engineering and metallurgical papers in this country and England, and were translated and printed in a number of papers on the Continent of Europe. Although the main contention of this study of steel from the standpoint of the user has to this day not been generally accepted, it is perhaps not too much to say that the influence of this investigation on the metallurgical world has been both deep and lasting. By it the steelmaker, as perhaps never before, was given a view of his product from the standpoint of the user, and in no uncertain manner was called upon to study steel, not alone with an eye to output, but also with an eye to the subsequent demands which the service would make upon it. It may not be amiss to add that many metallurgists have expressed appreciation and acknowledg-

ment of their indebtedness to this investigation for new ideas and stimulus in their study of steel.

Another and very important line of work in connection with the laboratory of the Pennsylvania Railroad at Altoona during these twenty-eight years has been the making of specifications for materials. This is, perhaps, the most exacting and time-consuming work that has been undertaken. No specification has been made, without a more or less exhaustive study of the conditions under which the material does its work, and these studies have not infrequently required two or three years or even longer, before a specification would be forthcoming. There are now some 43 specifications for different materials in use on the Pennsylvania Railroad, of which a part are purely physical, a part purely chemical, and a part jointly chemical and physical. Dr. Dudley can hardly be held responsible for all the specifications, but is responsible for the chemical part, and by way of consultation and suggestion, has helped with the others. The field for the making of specifications is far from being completely worked over as yet, and new ones are continually being made, as fast as information can be accumulated. But this making of specifications is only half the problem. The specifications tell what is wanted, but is the material wanted actually furnished? To answer this question involves tests of samples from shipments, as they are received, and it is a part of the scheme of the Pennsylvania Railroad Company, in connection with its Experimental and Testing Departments, to allow no bill to be paid until the material covered by it has either been inspected by a competent person, or been tested either physically or chemically, as the case may be. This scheme, so far as the chemical part is concerned, involves a thoroughly equipped laboratory, with a total force at the present time of eighteen persons, of whom twelve are regularly educated chemists. One of the force is likewise a regularly graduated bacteriologist, who has studied in Europe, and who is occupied in the examination of water supplies, experiments on disinfection, and in making bacteriological tests for diagnosis in connection with the Relief Fund. The total number of tests and chemical determinations made in the laboratory in connection with shipments of materials amounts to about 60,000 per year.

In this connection, several years ago, when the number of specifications had reached some thirty or more, it was thought

that if the reasons why, for the various requirements were put in print, it might serve some valuable purpose in making the specifications better understood by those desiring to furnish materials. This led to a series of articles, some twenty-five in number, in the " American Engineer and Railroad Journal," under the title of " Chemistry Applied to Railroads." Also under the same title, a second series of some thirty-one articles was published in the same journal, embracing the chemical methods involved in the examination of commercial products bought under specifications. These articles have attracted considerable attention, and although the series was started more than fourteen years ago, it is even now not rare for copies of the various papers to be asked for. It is the intention ultimately to bring the two series up to date, and issue them in book form.

As illustrating the influence of an Experimental Department on the constructions and practices actually in daily use on railroads, the studies under the supervision of the Laboratory on the " Ventilation of Passenger Cars " may be mentioned. These studies embraced a period of some three or four years, and resulted in the development of what is believed to be a very satisfactory system of car ventilation. When the studies were first undertaken, the ordinary passenger car either had no ventilation at all or at the best supplied to the passengers from 6,000 to 10,000 cubic feet of fresh air per hour. With the system as developed, 60,000 cubic feet per hour are supplied, or 1,000 cubic feet per passenger, and this air is warmed to seventy degrees in the most severe weather.

Space does not suffice to describe special investigations or further studies leading to modifications of practices, but it may not be amiss to mention that these investigations and studies embrace such subjects as car lighting, steam heating of cars, studies on disinfectants, resulting in the manufacture of a standard disinfectant by the Laboratory, studies on cast-iron for car wheels, and for other important uses, studies on paints, studies and long-continued tests on bearing metals, analyses of coals, examination of water supplies, both for boiler use and for drinking, and quite an exhaustive study of explosives, resulting in the formulation of rules governing the transportation of these and other hazardous materials.

Dr. Dudley has twice been abroad on business for the Com-

pany, once in 1886 to study oil burning on locomotives in Russia, and again in 1900, as delegate to the International Railway Congress in Paris. He has been Vice-President of the American Institute of Mining Engineers, and twice President of the American Chemical Society. He is at present President of the American Society for Testing Materials. He is a member of the English, French and German Chemical Societies, of the Iron and Steel Institute of Great Britain, and of the Verein Deutscher Eisenhuttenleute. He is also a member of the Society of Civil Engineers, the Mining Engineers, the Mechanical Engineers, and the Electrical Engineers of this country. He is a member of the Union League of Philadelphia, the Cosmos Club of Washington, and of the Engineers' Club of New York.

Apart from professional work, Dr. Dudley spends no small amount of time in connection with the Altoona Mechanics' Library, in which he is much interested. Under his supervision, and with the fostering aid of the Pennsylvania Railroad Company, this Library, which contains now over 35,000 volumes, is accumulating a collection of technical books, and bound scientific periodicals, which many a more pretentious library might be proud to own.

Dr. Dudley has never married.

It would be a difficult task to name an engineer who has had a greater and more varied experience in the testing of materials than Dr. Dudley. If we reflect that he is called upon to test and pass judgment upon the quality of nearly all the materials employed by one of the greatest, if not the greatest, railroad in the world, involving the expenditure of millions of dollars yearly, the magnitude of the task and of the responsibility fills us with reverence for the man able to shoulder it, with wonder at the presence in one mind of the many exacting qualifications required.

Dr. Dudley stands as the highest representative type of the testing engineer with a world-wide and richly-deserved reputation for integrity, skill and rare judgment, and, may we not add, unselfishness — for this will justify our further assertion that Dr. Dudley has no acquaintances — only friends.

# HEARTH AREA AND THE NUMBER OF TUYÈRES IN IRON BLAST-FURNACE PRACTICE*

### By F. L. GRAMMER

THE rapid advances on the mechanical side of blast-furnace practice have not always been accompanied by a proper appreciation of the metallurgical requirements. This is illustrated occasionally by the improper use of automatic barrow charging-devices, and bins (introduced at the expense of accuracy in weight) with ores of irregular composition or ores that have been poorly graded. The 100-ft. blast-furnace has not always been advantageous, and in many instances the increase in the number of tuyères, from 8 or 12 to 20, has resulted in decreased output. The data pertaining to this division of blast-furnace practice are now sufficiently complete to allow inferences to be made.

The use of fine ores has indicated the manner in which large outputs could be obtained, as it has emphasized the fact that intimacy of contact between gases and ore, and coke and air, were more important than the time of exposure. It was reasonable to suppose that if more points of contact were made between the air and the coke, their union would occur in a shorter period of time, and the coke would be burned more rapidly in the same-sized hearth, and an increased output thereby obtained. In consequence of this theory, many furnace men upon relining a furnace increased the number of tuyères from 8 or 12 to 20, or even more, frequently with unfortunate results. If the number of tuyères in an old furnace is increased while it is in blast and banked, there will be quite an increase in the output on resuming operations for a day or two, owing to walls having been cleaned. A single advantage which was obtained in one or two cases by the use of multiple tuyères has been offset by many disasters and, in at least one instance, the furnace wall was cut out within a period of two weeks. Unless the penetration of the blast is properly calculated, there is danger that it will go through the centre or up the walls of the furnace.

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* Read at the New York Meeting of the American Institute of Mining Engineers, October, 1903.

Apart from the increase in the number of tuyères, the points of horizontal contact also were increased by "oval" tuyères; "three-way tuyères"; and a very ingenious "fan-spraying nozzle," which has been described in "The Iron Age," November 25, 1897.

These patented tuyères, while hardly accomplishing the object for which they were designed, are not without merit. I have used the three-way tuyère very advantageously on furnaces having a dirty crucible, or having a lodgment on the wall, and by its use I have obtained a clean hearth. Owing to certain objections, however, these devices have never been extensively adopted in regular furnace practice, for if increasing the number of tuyères had shown more benefits, the practice would have been more widely adopted. The metallurgists of the present generation have experimented with the number of tuyères used, but no one, so far as I know, has had the temerity to place them in more than one horizontal plane in the last ten years.

The number of tuyères required in an iron blast-furnace must be determined from the hearth diameter, the fuel and ore used, and the grade of metal desired.

Taking up first the subject of blast-pressure. In a furnace having an 8-ft. hearth, the average distance through which the air at one point has to travel, in order to cover the whole hearth area, is the distance from the nozzle to the centre of the area, or four feet. If the air is introduced at two points, the distance is $0.5756 R = 2.3024$ ft.; at four points, $0.4 R = 1.6$ ft.; at eight points, $0.3482 R = 1.3928$ ft.; at 16 points, $0.3376 R = 1.3504$ ft.; and at an indefinite number (continuous) $0.3333 R = 1.3333$ ft.

As far as assisting blast-pressure is concerned, with a hearth of the same diameter, much relief in reducing the pressure cannot be expected beyond the use of eight tuyères. Indeed, the pressure necessary to overcome the resistance offered, as represented by the difference from the circumference to the centre of the area, will be greater in proportion to the number of tuyères, because of the greater friction offered by the smaller and more numerous channels which convey the air through the crucible. The three per cent assistance rendered by decreasing the distance from $0.3482 R$ to $0.3376 R$ is more than offset by the increased friction. The usual experience in using coke and a moderate quantity of fine ore is that, for the same volume of air and the same

hearth area, the blast-pressure with 16 tuyères will be from one to two lbs. higher than with eight tuyères.

Using from 16 to 20 tuyères usually means that the fewer tuyères are lost at scattered intervals by the splash or the drilling of molten iron; the tuyères wear out rather than burn out, and when one is destroyed the others follow quickly. With a larger number of tuyères the settling of the charge is apt to be more even than with fewer tuyères. Also, the dripping of the iron is less marked at any one tuyère. An observation through the peep-sight in the tuyère stock shows that the activity of the movement of the coke is noticeably less with 20 tuyères than with ten; the volume of the blast being the same in both cases and the diameter of the tuyères being such as to give the same penetration of the blast. However, a few extra tuyères are of advantage when the furnace is working irregularly; as it is very easy to plug the extra tuyères with clay when not needed. Appreciating the fact that it is safer to have extra tuyères, the tendency — even where no dreams of great benefit exist — is to increase their number.

For a given hearth area the number of tuyères that should be used is best determined by a comparison with the workings of a furnace of similar dimensions and engine equipment, operating under similar conditions of ore, flux and fuel, and grade of metal produced.

Excellent results have been obtained with Lake Superior ores in an 85-ft. furnace having a 11 or 12-ft. hearth and eight tuyères. For the purpose of illustration, assume a 11-ft. hearth, having the tuyères uniformly spaced; in this case each tuyère of equal diameter will cover an area of $\dfrac{\dfrac{\pi D^2}{4}}{8} = 11.87$ sq. ft., or, for all practical purposes, 12 sq. ft. If it was decided that the engines and stoves permitted a 14-ft. hearth, $\dfrac{\dfrac{\pi D^2}{4}}{11.87} = 13$ tuyères would be the proper number to have, and on account of columns, it is probable that 12 or 14 would be the number selected, the even number being more easily placed in the construction.

If with a 11-ft. hearth and eight tuyères, a blast-pressure of

ten lbs. per sq. in. were produced, the pressure calculated for 14 tuyères and a 14-ft. hearth would be as shown in the following formula:

$$\frac{7}{5 \cdot 5} \times \left(\frac{3482}{3400}\right)^2 \times 10 = 13.2 \text{ lbs.}$$

and adding one lb. for increased friction, the final blast-pressure would be about 14.25 lbs. Based on this reasoning, an increase in the number of tuyères will be beneficial.

In the light of our present knowledge it is assumed to be desirable that the horizontal area exposed to a single tuyère, or to a unit volume of air, should be constant for the same stock used.

Immediately after tapping the iron, the coke from 6 to 12 ft. below the tuyères is exposed for combustion. As the level of the molten slag and metal rises the coke becomes covered, and the air must seek coke at a distance more and more vertically above the tuyères, until at the flushing time the entire combustion, which has now become decreased in intensity, is above the tuyère level. After flushing, the lower limit of the combustion zone drops to the level of the cinder-notch, which is generally two feet below the tuyères. It is fair to asume that, at the same temperature of blast and with the coke of the same size and porosity, a unit volume of blast will attack a given volume of coke. Therefore, if the horizontal influence of a tuyère be restricted, and the blast volume remain constant, the vertical influence of the blast will be increased.

A hearth of small diameter means that the combustion zone extends to a greater height in the furnace than if the hearth were wide and receiving the same volume of wind. It means, also, that the heat is somewhat more intense, as is shown later in this paper. This explains in some measure the fact that the silicon-content of pig iron is usually higher with furnaces having a narrow crucible than with those having a wide crucible. In the former the dripping slag and metal remain longer in contact with the incandescent coke before reaching the bottom of the crucible, and a part of the coke is at a higher temperature than is usual in a furnace having a wider hearth.

I do not say that the consumption of fuel is better in furnaces equipped with a small crucible; because there are too many influences which act the other way. With a small crucible, more heat is lost per ton of metal produced, on account of the heat conveyed

away through the cooling devices; and in consequence there is less liability for the metal to break out. But, generally, small crucibles assist the assimilation of silicon, and furthermore, under ordinary conditions they can receive a hotter blast without sticking up the furnace than can the usual modern " jumbo." On the other hand, the increase of the horizontal hearth area allotted to a unit volume of the blast should decrease the vertical height of the combustion zone. If this be correct, a 70-ft. furnace would derive more benefit by increasing the number of tuyères than would a 100-.ft furnace, because, by decreasing the height through which combustion takes place, we have practically added to the height of the furnace, and for Lake Superior ores a 70-ft. furnace is probably too low for best economy of fuel. An increase in the number of tuyères is analogous to an increase in the area of horizontal influence. My assumption, that each point in the horizontal plane of the hearth at the level of the tuyères receives the same quantity of air, is probably exaggerated, even with coke. With a sticky fuel or with fine ores poorly distributed, it is quite certain that the air does not pass around the fuel as freely as water would fill the interstitial space in a pail filled with marbles. Under these conditions, the more contact possible between air and coke the better. Two reliable instances of marked improvement, resulting from an increase in the number of tuyères without increasing the engine-power or hearth diameter, were obtained in a low furnace treating a charge of 75 per cent Mesabi ore, and in a furnace using anthracite fuel.

If small hearths assist to make high-silicon iron, large hearths tend to make low-silicon iron; in other words, an increase of the number of tuyères tends to lower the silicon in the pig iron produced in the furnace.

With eight tuyères, the tuyère is 0.3482 ft. distance from the centre of its area of control, which extends over the entire space in front of the tuyère. In a hearth 12 ft. in diameter, the deflection that air would have to one side, before it meets air from the adjacent tuyère, is shown in the following equation:

$$\frac{\pi\, 12\, (1 - 0.3482)}{16} = 1.53 \text{ ft.} = 18.4 \text{ in.,}$$

or, with 16 tuyères,

$$\frac{\pi\, 12\, (1 - 0.3376)}{32} = 0.78 \text{ ft.} = 9.4 \text{ in.}$$

Using a hard coke, no marked improvement or change could be expected by decreasing the wall of coke below 18 in. to nine in. Coke in a finely divided form and anthracite of small sizes, would hardly find a thickness of 18 in. a barrier to the passage of air. This may explain why many have noticed no improvement in furnaces working under regular and healthy conditions of large and strong coke by increasing the number of tuyères on the same hearth-area.

In determining the size of hearth, it is obvious that the character of fuel must be taken into consideration. A fuel with cellular structures, aside from its disadvantages in the upper part of the furnace, will burn more rapidly than one more dense. Coke having a cellular space of 45 cu. in. (a unit size), compared with charcoal having 150 cu. in. cellular space in same volume, certainly requires a different dimension for the hearth area. Of course, coke is not quite so far behind charcoal as the ratio of 45 to 150, because the combustion of coke is assisted by the great pressure under which these furnaces are operated. The hearth area, besides being controlled by the fuel, should increase in proportion to the additional volume of air deliverable by the engines, as well as to the heat obtainable from the stoves. It required nearly a decade to learn that an increase of 40 per cent in the diameter of the hearth necessitated a 100-per cent increase in the engine equipment of the plant, not to mention the stove-capacity.

The other features of the hearth, such as height of cinder-notch and iron-notch, cubic capacity compared to total furnace capacity, etc., have been discussed in former contributions to the " Transactions."

We have discussed the pressure, diameter of hearth and number of tuyères, for metal of the same grade using a constant and an increased blowing capacity; yet the selection of the most desirable diameter of hearth for a set of entirely new conditions is a problem which can only be settled empirically.

The present treatment of Lake Superior ores with Connells-ville or hard coke in furnaces equipped with modern engines is to have a volume of air sufficiently large to fill the empty crucible once every two seconds. A unit volume of air attacks a unit volume of coke, presenting a constant area of surface; and it may be said further that, at the same temperature, the quantity of coke burned varies almost directly as the weight of air sup-

plied.  If the volume of air per pound of fuel consumed did not vary from 53 cu. ft., under the best conditions, to 120 cu. ft., in plants having leaky valves, poor engines and split stove casings, we could speak of volumes in place of weights.

In the year 1883 Mr. Witherow thought that at a temperature of from 1,300 to 1,500° C. 140 cu. ft. of air per minute, in a furnace using coke or anthracite, would produce one ton of cast iron in 24 hours; and using charcoal, 110 cu. ft. of air per minute would produce one ton of cast iron.  At the present time 85 cu. ft. of air will produce one ton of cast iron under conditions similar to those just quoted.  This difference is really very slight, considering the lower fuel consumption incident to the lower silicon-content of the resultant cast iron, together with the richer and more easily reduced iron ores used.

It is known, also, that at higher temperatures iron dissolves more carbon, *i. e.,* makes richer iron, and, other conditions being equal, the iron will contain more silicon.  Thus, in order to increase the percentage of carbon and silicon in the cast iron produced, the temperature of the furnace must be increased, which is accomplished by using less ore and a more siliceous slag.

It is known that the reduction of magnetites requires a high temperature of the gases escaping from the furnace, or that the gases should be rich in carbon monoxide, and, consequently, the quantity of coke burned for a given unit of iron is greater than that resulting from the treatment of Bessemer ores.  These remarks apply also to ferro-manganese and to silico-spiegel in a greater degree; as the cooling effect of the descending stock does not reach so low in the furnace and, consequently, the temperature in the crucible is higher.  The use of soft fuel which will dissolve in the top of the furnace means that more fuel will be required to do the work in the crucible.

A porous fuel, like charcoal, with the pores open and not sealed, as in coke, offers from eight to ten times the contact surface on a given weight of fuel for attack by the blast, and its combustion therefore occurs lower in the furnace.  The occluding power of charcoal causes it to ignite at a very low temperature. If it were desired to make an iron at a heat near to its freezing-point, such as basic iron or forge iron, a fuel easily ignited (charcoal) would be advantageous, especially if cheap and abundant.

Schinz, in 1868, says that the one point about furnace lines

of greatest unanimity of opinion is, that wide hearths are better adapted to forge iron and narrow hearths to foundry iron. He also gives the calorific intensity of coke about 100° higher than that of charcoal.

The better sorting of the ores, the more uniform quality of the coke and the more regular charging of the furnace have resulted in reducing the irregularity in the working and have diminished the demand on the heat of the crucible, consequently a smaller margin of heat in the crucible was permissible and the

*Change in the Factors of Iron Blast-Furnace Practice*

| Time | Place | Cu. Ft. of Furnace Per Ton of Metal Produced in 24 Hours. | Remarks |
|------|-------|------|---------|
| 1854 | England | 190 | . . . . . . . . . . . . . . . . . . . . . . . . . . . . . |
| 1870 | England | 380 | Resulted from increasing the height of furnace from original 45 ft. to 75 ft. and more. |
| 1876 | United States | 197 | Height of furnace from 65 to 75 ft. |
| 1889 | United States | 59 | Lake Superior ores; smaller proportion of lump sizes; crushed more thoroughly; lower bosh; large volume of air. |
| 1891 | United States | 50 | . . . . . . . . . . . . . . . . . . . . . . . . . . . . . |
| 1903 | United States | 20 to 30 | Mesabi ores; wider hearth; increased volume of air; lower silicon in iron. |

silicon-content of the resultant cast iron became lower. The crushing of the ores and the lowering of the bosh has allowed the silicon-content of the cast iron to be lowered without danger of increasing the sulphur-content, or of having the charge stick on account of the larger ratio of lime to total silica-content in the burden. These results have met with the approval of those interested in developing the practice of smelting Bessemer ores.

A wide hearth will contain a large quantity of molten metal and, acting like a " mixer," it reduces any temporary irregularity

in the composition of cast iron, thereby yielding a product of greater. uniformity. A soft fuel, with a dull lustre, like charcoal, radiates and absorbs heat more rapidly than a hard fuel, with metallic lustre, like coke or anthracite.

In less than 30 years the ratio of hearth area to greatest bosh area has increased from one-sixteenth to nine-sixteenths, and the furnace capacity in cubic feet per ton metal produced has changed.

The data given in the table (see page 273) show that the fine size of the ore allows a lower silicon-content of the pig iron produced and yields a better contact of blast, which permits an increased volume of air to be used and a corrsponding decrease in the time of exposure.

Schierz says that the time of exposure in the reduction zone should be relatively 4.53 for spiegeleisen, 2.75 for foundry iron and one for forge iron. He says, also, that these ratios can be reduced by increasing the volume of air.

Gruner gives, as a desirable diameter for the crucible of furnaces using charcoal, 20 in. up to nine feet, and for furnaces using coke, up to ten feet. For furnaces using coke he gives the following cubic capacity of the crucible: Furnaces producing from two to five tons of pig iron in 24 hours, from 18 to 36 cu. ft.; producing from five to ten tons in 24 hours, from 36 to 62 cu. ft.; producing from 10 to 20 tons in 24 hours, from 72 to 144 cu. ft.; and producing from 40 to 60 tons in 24 hours, from 216 to 288 cu. ft.

Modern American practice is from 3 to 3.5 cu. ft. of crucible capacity per ton of metal produced in 24 hours. Gruner says that for lean ores the size of hearth is greater per ton of metal produced than for rich ores. These early authorities are quoted merely to show their ideas on the subject.

Practically, for the same volume of air the silicon-content of the resultant cast iron may be raised, or a more refractory charge reduced, by lightening the burden, an act which raises the zone of incandescent coke and usually increases its temperature. The temperature of the hearth also may be increased by raising the temperature of the blast. On the other hand, on those ore and other material which have not been proven to be as independent of time exposure as are Lake Superior ores, the inclination is to use a lesser quantity of blast, which suggests a smaller hearth

diameter commensurate with the reduction of blast, in order to give a longer time of exposure.

For porous materials like charcoal, conditions opposite to those for coke hold, and being soft it requires a smaller hearth, because of the pressure of the superincumbent charge and because it offers so large an area of surface contact for attack.

For hard, dense materials like coke, offering fewer surfaces of attack on a metal requiring small fuel margins, such as basic iron, a shape of furnace is desirable which will allow the quick removal by the rising gases of the heat generated, and that shape is a wide hearth. Furthermore, a wide hearth offers the proper volume of coke to the attack of the blast, and with a low vertical ignition the spreading of the heat is facilitated laterally more than vertically for the same quantity of air. This may mean a slightly lower temperature at the hottest region.

I hesitate to say exactly what is the proper hearth for the production of an iron of a given silicon-content, because economy in coke consumption is regarded differently in different localities. Some metallurgists think that where coke is expensive, the hearth area in making foundry iron should bear approximately that relation to the hearth area in making Bessemer metal as the Bessemer time-exposure does to the foundry-iron time-exposure. This is to be the relation if the furnaces producing foundry and Bessemer irons have the same stove and engine equipment, the same richness of ore and the same nature of the ore apart from phosphorus. This statement is crude, but it holds true in general. The natural field for experimenting on the dimensions of the blast-furnace has been in those furnaces producing Bessemer irons, as they are usually assembled in larger units near together, and hence are more easily compared and studied.

" Inversely as the coke consumption " might be considered a better rule for varying the diameter of the hearth.

When the relation between hardness and calorific intensity, porosity and rapidity of ignition — softness and solubility in carbon dioxide — (disregarding the chemical per cents) have been shown by our technical schools, we can speak other than by rule of thumb.

## SIDE-BLOWN STEEL CONVERTERS*

### By N. LILIENBERG

STEELMAKERS are divided as to the economy of making castings from Bessemer steel blown in small converters with horizontal tuyères. Large amounts of money and work have been spent on experiments and some manufacturers have discarded the process after it had been duly installed and operated. This naturally causes others to hesitate and hampers the progress in the whole. Everything depends on the method being carried out in the right way; we then know what to expect from it. I give below some observations, after having consulted several experts and having seen some plants of this kind in operation. Most of the previous publications have been made by agents advocating a special construction, claiming all possible advantages for it and hiding the disadvantages. I am agent for no steel process and will try to take the independent stand of a manufacturer investigating whether it will pay him to erect such a plant. It is, of course, impossible to exhaust the matter entirely, because a number of people are working with improvements, which may change the aspect after a while. In gathering information I am especially indebted to Mr. Bradley Stoughton, of New York City, who has made many investigations in this line.

### THE MARKETS FOR DIFFERENT CASTINGS

It has been generally conceded that the superheated steel made in side-blow converters cannot compete with open-hearth and bottom-blown steel for heavy castings and for ingots to be rolled and forged. The field at present mainly assigned to it includes castings of light weight, thinness and of ornamental designs. It would be impossible to fix an upper limit for the weight, but I have been informed that several ten-ton castings have been made from two-ton side-blow converters, the superheated steel being retained in a ladle until the next charge is blown. The lower limit can be said to be only a few pounds. Side-

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* A paper read before the Philadelphia Foundrymen's Association, January, 1904.

blown steel has a place between crucible and open-hearth steel. The castings have mostly no higher carbon than 0.25 per cent and it would be too expensive to melt such steel continually in crucibles.

It was my intention to make some kind of classification by comparing illustrated catalogues and price lists of different foundries, but these are not generally issued on account of the endless variety of new shapes. In a general way it may be said that small castings from superheated steel may compete with cast iron, malleable iron, drop forgings, pressed steel and bronze. The competition with cast iron can only take place in cases where lighter weight with the same strength is desired. This is especially the case with naval constructions and with running machinery; thus, with wheels of all kinds, cogwheels, pulleys, small truck wheels, etc. The competition with malleable iron will depend on many local circumstances. That process can only penetrate to a certain depth and takes a comparatively long time, in both of which the steel has the advantage. On the other hand the castings of malleable iron are more easily made and the sink-heads and gates are much easier to remove and dispose of. There is undoubtedly a field for competition with drop forgings for a numerous variety of soft steel tools and other objects. These must, however, be limited to cases where no special strength is required, because a drop-forged article made from rolled steel is undoubtedly stronger than a steel casting. The same thing applies to cold-pressed sheet steel which has of late come into extensive use. In ornamental castings bronze, of course, takes the lead, but many objects are made of cast iron and painted bronze. There are, however, some lower limits beyond which it does not pay to make those small articles of cast iron, and here soft steel can take its place. It is doubtful if such steel will come into use for stoves, as cast iron properly constituted will fill out all the ornamental designs required and no special strength is needed.

*Dynamo Magnet Steel.* — It has proved possible to produce superheated side-blown steel entirely sound, uniformly lower in carbon and manganese than any open-hearth or bottom-blown steel. As the manganese is, above everything, objectionable to the permeability, many tests have shown that with the ordinary magnetizing force it has been possible to increase the induction about ten per cent by using the above-named steel. This is what

is claimed by M. Tropenas in a pamphlet and has been corroborated by outside impartial parties. The permeability and hysteresis curves from such steel in fact approach those of Swedish iron. To demonstrate the great influence of manganese in this respect, I may mention a case under my observation, comparing two irons where the permeability was greater, although the carbon was three times as high only on account of the absence of manganese.

*Centrifugal Castings.* — The many devices to make steel castings hollow in a rotary mold have principally met with the obstacle that a large quantity of open-hearth steel cannot be kept liquid long enough for casting, rotating and removing hollow ingots. But it seems to me that the question could be brought to life again now that superheated soft steel can be obtained in small quantities from side-blow converters. Having made some investigations in that matter, I hope to return to it on another occasion.

*Ingots for Rolling or Forging.* — As far as I know these are not regularly produced in appreciable quantities from side and surface-blown steel. It is impossible for a two-ton converter to compete in cost of production with large sized bottom-blown or open-hearth furnaces. There are, however, cases where it seems to me advisable to make ingots in that way. When charcoal pig iron is not remelted but taken direct from a blast furnace in batches of two to three tons and when silicon does not exceed one per cent, the blows in the converter are sometimes troubled with spitting and the steel is not quiet enough in the molds. It seems to me well to raise the heat in the converter by burning the carbonic monoxide and to keep the metal less agitated. For well-known reasons it is not desirable to pour the steel too hot in cast-iron molds for ingots, but this could be regulated by adding cold steel scrap in the converter. The last named conditions fit many of the Bessemer works in Sweden, but I am not prepared to advance this as a definite opinion before all conditions as to economy are known.

*Hard Steel.* — As far as I know, the bulk of the side and surface-blown steel has carbon not above 0.25 per cent. I have not heard of any instance where higher is produced in that way by breaking off the process earlier, but there are some cases where recarburization is accomplished by additions after the blow for such purposes as spring and common-tool steel.

## UNIFORMITY IN CHEMICAL ANALYSIS

It has been claimed that side-blown steel runs more uniform in composition than open-hearth steel. I give here below some comparing analyses of steel castings made by the acid process, the figures reported being taken from consecutive charges and not selected:

### *Open-Hearth Steel, Newark, N. J.*
### *Crucible Steel Co. of America.*

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| C .... | 0.31 | 0.26 | 0.21 | 0.26 | 0.33 | 0.40 | 0.41 | 0.41 |
| Mn .. | 0.47 | 0.74 | 0.45 | 0.74 | 0.75 | 0.74 | 0.55 | 0.56 |
| Si ... | 0.25 | 0.28 | 0.22 | 0.25 | 0.28 | 0.34 | 0.30 | 0.28 |
| P .... | 0.048 | 0.051 | 0.058 | 0.071 | 0.025 | 0.060 | 0.058 | 0.045 |
| S .... | 0.027 | 0.027 | 0.030 | 0.054 | 0.030 | 0.030 | 0.036 | 0.028 |

### *Side-Blown Steel, St. Paul, Minn.*
### *American Hoist & Derrick Co.*

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| C .... | 0.27 | 0.28 | 0.26 | 0.28 | 0.24 | 0.24 | 0.24 | 0.25 |
| Mn .. | 0.78 | 0.81 | 0.76 | 0.76 | 0.97 | 0.78 | 0.82 | 0.75 |
| Si ... | 0.25 | 0.28 | 0.23 | 0.29 | 0.26 | 0.23 | 0.25 | 0.21 |
| P .... | 0.051 | 0.050 | 0.049 | 0.051 | 0.048 | 0.053 | 0.052 | 0.045 |
| S .... | 0.034 | 0.039 | 0.033 | 0.037 | 0.024 | 0.033 | 0.039 | 0.039 |

It will thus be seen that the carbon is somewhat more uniform in the side-blown steel, but that otherwise the variations in the elements are about the same. The high and variable percentage of manganese comes, of course, mostly from the addition of ferro-manganese.

A metal free from manganese, for electrical purposes, can only be produced in side-blown converters by continuing the operation until the carbon is about 0.10 per cent. Steel thus produced has analyzed in average:

Carbon ........................... 0.10 per cent
Manganese trace to................ 0.04 per cent
Silicon .......................... 0.02 per cent
Phosphorus ....................... 0.04 per cent

Some very mild bottom-blown Bessemer steel has been produced, especially at Homestead and Bethlehem Steel Works, the carbon going down as low as even 0.07 per cent and the silicon

about 0.010 per cent (in some cases even 0.04 per cent), but the manganese is at the same time up to about 0.40 per cent. The pig iron to be used for the side-blown converters need not contain over 1.5 per cent silicon, as so much extra heat is obtained by burning the carbonic oxide inside the converter. This is an advantage considering that silicon is an expensive fuel for the converter. I have recently got an inquiry for Bessemer pig iron of the following composition:

> Silicon ........................... 1.50 to 2.50
> Sulphur not over.................... 0.04
> Phosphorus not over................ 0.04
> Manganese about.................... 1.
> Total carbon about................. 4.

It is not stated whether it is intended for side or bottom-blown, but there can be no doubt that it is for the latter. The manganese in the side-blown pig iron should not exceed about 0.50 per cent, as it would among other things greatly increase the heavy wear of the lining.

### MECHANICAL PROPERTIES

It has been claimed that side-blown steel invariably is absolutely sound and free from blow holes. This ought to be modified so far that the metal is generally sounder than open-hearth or bottom-blown steel; but by wrong manipulation it is quite possible to produce honeycombed steel by side-blow. That it is generally dead molten depends mostly on the great fluidity which allows the gases to escape and not on the fact that no air is driven through it. The results from pulling tests of side-blown steel do not in average indicate any superiority over good open-hearth or bottom-blown steel of same composition. The annealed side-blown steel castings whereof analyses have been given above with carbon 0.24 to 0.28 per cent show mechanical properties whereof the following extracts may give an idea:

> Elastic limit........29,350 to 42,900 lbs. per sq. inch
> Ultimate strength....63,800 to 71,900 lbs. per sq. inch
> Elongation ..........38,50 per cent to 28. per cent

Just as with other steel the annealing and forging improve the mechanical properties. Very good cold-bending tests have been shown of side-blown steel, but it has not been demonstrated that other sound steel of the same composition and treated the same way cannot stand the same tests.

### Advantages of the Small Controverter

When the question confronts a manufacturer whether he ought to erect a plant for making side-blown steel, the first thing to be considered is his facility for marketing the products. I have said that for electrical purposes a new metal is produced simultaneously low in carbon and manganese. Outside of that the advantage is not in the quality but in the greater possibilities by obtaining superheated dead molten metal in small quantities. The bottom-blown converter can produce small castings with the first part of the charge, but it takes so long to pour out the steel in that way that the metal would be too cold at the end of the pouring and heavy skulls formed. The open-hearth furnace cannot produce steel hot enough for small steel castings without a great deal of expense in refractory material. On account of the high temperature of the metal from side-blown converters it can be poured over the lip from small ladles in the same way as ordinary cast iron from a cupola without leaving much skulls. It has even been found by some steel makers that side-blown steel cannot be tapped from the bottom by a stopper because the lining is cut out from the tap hole.

I quote below literally three advantages from Mr. Bradley Stoughton's valuable paper on the subject:

"The plant of side-blown converters is cheaper to install. The first cost of an open-hearth furnace is much more than that of a converter plant, but thereby has to be taken into consideration, that on account of the length of time necessary to repair a converter with fixed bottom and because these repairs are necessary every 20 heats, on the average three vessels must be installed to keep one working continually, for at any one time one converter is working, one is repairing, and the third is drying. A plant of three two-ton converters would thus replace an open-hearth furnace of from 50 to 70 tons daily capacity. The blowing engine and motor are, of course, much cheaper than for a bot-

tom-blown converter. Any blower of the two impeller type capable of giving the necessary wind may be used.

"The converter may be shut down and started up at short notice. An open-hearth furnace must be run continually to be at all economical, while the chief additional expense of running the converter intermittently is the small amount of fuel to heat up the apparatus before the first blow. This advantage, however, only applies to the following limited classes of manufacturers:

"1. Those who have ample room and prefer to do their work by daylight.

"2. Some cast iron and malleable iron founders, who are frequently called upon to furnish steel castings to good customers, but do not have a large, regular or steady demand. Under these circumstances they are wont to subject such contracts to steel foundries with the result of divided profits and occasional serious delays in delivery or defective castings furnished, for which they are accountable, but not directly responsible.

"3. Manufacturers who need a few thousand tons of steel castings a year to put into the product of their own factory, but whose requirements are not large enough to warrant running continuously an open-hearth furnace of economical size. In the United States there are several concerns of this class, who have put in a side-blow converter plant.

"4. Open-hearth foundries which have occasional desirable orders for castings not suitable to open-hearth steel, on account of being small or with thin sections, or with special chemical requirements. Thus a good customer may desire small bevel gears in large quantities, with high carbon to give good wear, or a locomotive works will often send out orders for several large castings together with a number of small ones. To get the desirable work the foundry may take the order and sublet the small work to another foundry at an actual loss to itself, relying on the larger work to make this up and also furnish profit for both parties.

"5. Also in general any foundry expecting fluctuating orders.

"It is better to have a small amount of metal coming to the foundry at frequent intervals:

"1. Because of greater possible variation in chemical composition and consequent elasticity in fulfilling different physical re-

quirements. Each unit of steel must be uniform in chemical composition and with large units it is difficult to fit them exactly to the different orders. It is impossible to divide units into small units, unless the steel is extremely hot, because the steel loses too much heat by radiation on standing or during repouring. This is an advantage of constantly increasing importance with the more extended use of steel castings in many industries. Alloy-steel castings, hard steel for wearing purposes, soft steel for ordinary castings, or extra soft for electrical purposes, are often called for, perhaps all on the same order.

" 2. Because of the better arrangement of the work, since the pouring may be done by one gang who do nothing else, and become very expert at it in practice, while the rest of the shop is not interrupted at all in its regular work. When the pouring is done in large units it takes a number of men to do it and the whole shop is more or less interrupted for twenty or thirty minutes, three or more times a day, depending on whether the foundry is served by one or more furnaces. The amount of time lost in this way must be weighed against the wages of the extra men needed for continuous pouring and each shop must strike its own balance. Again, the crane or the apparatus for pouring must be more powerful when pouring in large units. When pouring in small units and continuously, this apparatus is never available for anything but pouring and an extra one must therefore be kept for the purpose.

" 3. Because of the smaller floor space required for setting molds. The work of molding, setting, pouring and knocking out can go on continuously in a small space and this is a valuable economy in a foundry."

Having thus mentioned several bright sides of the side-blown steel process, I wish to say a few words about

### DISADVANTAGES

It is well known that several manufacturers have abandoned their plant for making side-blown steel. The reasons generally attributed are waste of metal and of refractory materials. The normal difference of weight between the pig iron charged in the cupola and steel obtained at the mouth of the converters is 14 to 17 per cent. How much of this stands as actual waste in the

converter is somewhat uncertain because the melted pig iron is generally not weighed. But the loss in the cupola alone should not be above five per cent and the total amount of silicon, carbon and manganese about six per cent. The remaining three to six per cent is of course not much. But at several works the loss of iron amounts to considerably more than 17 per cent and even runs up to 30 per cent continuously for months. It is admitted that more iron is burnt inside the surface-blown converters than in a bottom-blown, which is also evidenced by a greater amount of oxide of iron thrown out in the shape of red smoke. There is also a complaint that the side-blown converter spits more slag and steel than the bottom-blown. This, however, looks doubtful to me and the side-blow charges I have witnessed have been as a general thing absolutely clean. Excessive burning and throwing out of metal depends to a great extent on defective management; for instance, too cold iron, wrong composition of the pig iron; faulty regulation of the blast, burnt-out lining and tuyères whereby the blast is not delivered in straight well-defined lines, or wrong position of the converter. Altogether it requires more skilled labor and attention to manage a side-blow than a bottom-blow.

The greater waste of the lining depends on the higher heat, combined with a larger amount of oxidized iron which saturates itself with more silica than resulting from the burning of the silicon in the pig metal. This was of course aggravated in the previous constructions where the side-blow was delivered under the surface, thus giving a rotary motion to the steel. It remains to find a durable lining for side-blow converters. The bottom is more rapidly worn than the sides and recently constructed improved converters therefore have detachable bottoms. By bottom is meant the whole lower part including the tuyères. This lasts 10 to 20 heats if it is kept in good order, and the superstructure lasts about 40 to 50 heats. By constant patching the lining in the Tropenas converter can last about 150 heats. In bottom-blown converters the bottom lasts about 25 heats and the upper lining 200 to 300. The economy of refractory material of course depends also greatly on the quantity to be renewed. This is larger if the division line between the top and bottom is above than below the trunnions. In the last named case the bottom part can also be more easily changed. In the bottom-blown converters the in-

terchangeable part constitutes of course a much smaller percentage of the whole, as no part of the sides is attached to the bottom.

## Waste of Metal After the Blow

The waste of metal after the steel has left the converter is caused by three circumstances:

Spattering during the pouring which amounts to one to two per cent, depending on the size of the castings.

Skulls in ladles proportionately to the heat of the metal.

Sinkheads and gates which naturally constitute a larger percentage the smaller the castings are. These can of course be made thinner the hotter and quieter the metal is. The work in getting off the sinkheads is a considerable item in the making of small castings. They cannot be knocked off with a hammer but have to be either sawed off close to the casting or chipped off and the root ground, which is generally more work. This is a drawback in small steel castings by whatever process. The question what to do with all the steel scrap, whereof the sinkheads and gates under normal circumstances constitute the largest proportion, should be carefully considered. When the converter plant is isolated the steel scrap will have to go into the cupola and the amount thus to be consumed will generally have to be limited to 25 per cent. The steel requires more fuel to melt and higher temperature. Besides the pig iron is thereby diluted and the silicon lowered which is the expensive fuel on which the heat in the converter to a great extent depends. Then there is always danger of delivering the pig metal too cold to the converter if too much steel scrap is melted. The amount of scrap from small steel castings can easily exceed 25 per cent, and then the scrap heap in front of the cupola will constantly increase. The excess will have to be disposed of at a loss to open-hearth steel makers. The side-blown converter therefore works to best advantage in conjunction with an open-hearth furnace, which can consume the scrap with expenditure only of coal and labor, leaving the cupola undisturbed for melting the pig iron.

## Construction

I will here only refer to those converters which are in practical use, leaving the others to be mentioned in the historical

sketch.   As far as I have been able to ascertain, side-blow steel
is only made in America by the following three processes:

The Tropenas converter has a double row of tuyères, the up-
per one being intended to burn the carbon oxide inside the con-
verter, thus increasing the heat.   The tuyères are either parallel
or converging towards a point beyond the center of the converter.
The upper or combustion tuyères are rectangular or oval with the
large axis horizontal.   Both rows of tuyères pass through a pro-
jecting ledge in the lining of larger diameter than the converter
itself and are intended to check the rotation of the steel.   The dis-
tance between the rows is four to seven inches.   The diameter of
the lower tuyères is 1.25 to two inches according to the size of the
charge.   One object of the tuyères being laid in such a concave
ledge is that in case of the metal running into the outer longer
ones, warning will thereby be given before all are stopped up.
The lower part of the converter is conical for one ton and cylin-
drical for larger sizes.   The bottom is fixed and the relining is
done through a manhole.   As above mentioned it is thus necessary
for continuous operation to have three converters, one for repair,
one to be dried and one in operation.

The long tuyère modification as built by Mr. B. Stoughton
has only one row of parallel tuyères one and a half to two inches
placed in the flat side of the converter.   The constructor has the
view that a better result can be obtained by burning the carbonic
oxide close to the surface of the metal bath and four inches to
seven inches above, as in the Tropenas construction and that this
can be accomplished by only one row of tuyères.   He also found
that the second upper row, unless very carefully watched, is liable
to furnish excess of air representing loss of blowing power and
loss of heat by cooling.   The tuyères are made by iron pipes
rammed into the lining, the ends projecting about six inches into
the wind box.   The distance between the tuyères and the mouth
is increased about 50 per cent over that of Tropenas construction
in order to reduce the loss by spitting.   The lowest part is de-
tachable whereby only one, at most two, converters are needed,
as the bottoms give out earlier than the superstructure.   Both of
the said converters revolve in the ordinary way on trunnions
through which the blast is delivered.

The third of the side-blow converter type in active operation
is the Evans-Wills, delivering the blast through flexible pipes

and having the turning center below the bottom of the converter. The lower part with the wind box attached is removable from the superstructure and placed on wheels. After the blow it is rolled away and used as a ladle for casting in different places. A hole in the upper edge serves to rake out part of the slag.

In all side and surface-blown converters the diameter and the depth under the tuyères should not exceed certain limits if the action is to be thorough. I lay special stress on this because there are parties here who have spent lots of money and suffered agony of mind before they found out that the only trouble was too great depth of the metal bath. Makers of small castings have generally stopped at two-ton converters, but larger ones are contemplated. As it is not safe to increase the depth or diameter, the only dimension which could be extended is the width, making the cross section elliptical and giving the converter room for more tuyères. This, however, has to be. The cupola melting the pig iron is either on the ground, when the liquid metal has to be lifted by an elevator to the mouth of the converter, or the metal may run down from the cupola to reach the converter. In the former case the advantage is gained that the pig iron can be weighed and sample taken to find out whether the pig metal after being melted is suitable for the blow. But on the other hand one more elevator has to be furnished which is more expensive than to elevate the raw materials for the cupola a few feet higher, and the pig metal loses some heat by being poured in a ladle.

As the blast pressure is only four lb. per sq. inch and it is the question of volume and not pressure an ordinary blower with ordinary twin impellers can be used for cupola and converter alike. The power required is about one-tenth of that for bottom-blown converters.

## OPERATION

As it is important that the blast should be delivered in an acute angle just above the surface of the metal the quantity poured into the converter will have to be regulated accurately (in a bottom-blown converter, of course, no attention needs to be paid to this). After the filling the converter has to be placed just in the right angle by turning the wheel of the gear, opening the back of the wind box and looking through the tuyères. The blast

ought to strike the metal about half way across and be delivered in well-directed parallel currents. Irregularity in that respect will cause more spitting. During the first period, 25 to 30 per cent of the whole, only sparks and red smoke appear, the last named from oxide of iron showing up to a greater extent than in a bottom-blown converter. The liquid metal is not at rest but has the rotary motion of a wave and the action can therefore only extend to a certain depth. As in all converting processes the basic silicate of iron first formed acts on the carbon, thereby forming carbonic oxide, which helps to keep the metal in motion although of course the agitation is much less than in converters where the air comes in under the surface of the metal. As the flame becomes white and strong during the boiling, the blast pressure is reduced to three or three and a half lbs. and the converter is tilted slightly backward. During this boiling period, about one-third of the blow, there is no red smoke. Then the flame drops. Whenever the flame is short, red smoke appears. The spitting is worst towards the end of the boiling period. Then the flame lengthens a second time and becomes clear and white, until the final drop at the end of the blow, during which last period full blast is turned on. If spitting occurs during the last period, there is something wrong in the lining, the tuyères or the position of the converter. The blow of two tons lasts about 20 minutes. Analyses of the escaping gases show about the following proportions:

|  | CO | $CO_2$ |
|---|---|---|
| 4 minutes from beginning.................... | 0.00 | 8.2 |
| 10 minutes from beginning boiling............ | 0.30 | 24.3 |
| 12 minutes from beginning boiling............ | 0.40 | 8.8 |
| 17 minutes from beginning shortened flame.... | 10.70 | 12.0 |
| 21 minutes from beginning, end. | | |

Corresponding analyses of gases from a bottom-blown converter have appeared as follows:

|  | CO | $CO_2$ |
|---|---|---|
| 4 minutes from beginning.................... | 3.95 | 8.59 |
| 10 minutes from beginning.................... | 19.59 | 3.58 |
| 14 minutes from beginning.................... | 31.11 | 1.34 |
| 18 minutes from beginning, end. | | |

It will thus be seen that in the side-blow the carbonic oxide is well oxidized during the boiling; after that it is increasing until the end of the blow. At the late period when about ten per cent each of carbonic oxide and carbonic acid appear, there is also about seven per cent free oxygen. This depends on the inaction of the carbonic acid during the excessive heat and of course no amount of extra air would then burn the carbonic oxide. This also accounts for the apparent anomaly that the flame at the end of the blow is at least just as long as in a bottom-blown converter for the same carbon. The analyses of gases from the last named show a steadily increasing amount of carbonic oxide. These circumstances make it more difficult to determine the carbon by the appearance of the flame in a side-blow converter. But this is simplified because as far as I know the bulk of the side-blown steel has either 0.25 or 0.10 per cent carbon. Although the economy of heat in the converters has been several times exposed I think it would be of interest in connection with this matter to repeat some of the figures.

The units of heat (that is the multiples of heat needed to raise one lb. of water one degree) developed by the combustion are as follows:

Hydrogen ........................................... 34,462
Silicon ............................................. 7,830
Iron ............................................... 1,650
Carbon to carbon monoxide........................... 2,474
Carbon monoxide to carbonic oxide................... 2,403
Carbon to carbonic acid............................. 8,080

The silicon therefore gives a considerable amount of heat which stays in the metal, the product being liquid. The iron gives some heat in burning but this to a great extent is taken back when the iron oxide is dissolved in contact with the carbon. Some heat must also be developed by the oxidation of manganese and by the combination of the silica with the oxides, although I have never seen an estimate of the last named. The oxidation of the carbon to carbon monoxide in the metal bath gives 2,474 units of heat per unit of carbon. But only part of this is given to the steel because the product of combustion takes flight and carries away the bulk of the heat from that source. By burning the car-

bonic monoxide outside the metal bath and inside the converter additional heat is obtained to the extent of 2,403 units of heat per unit of carbonic monoxide.  But inasmuch as one unit of carbon corresponds to 7-3 units of carbonic monoxide the additional heat thus gained referred to the unit of carbon in the pig iron will be 7-3 × 2,403 = 5,607 units.  This is quite a considerable increase, but only a limited amount of this is imparted to the steel, the bulk of the hot gases instantly leaving the converter.  The result would be better if it were possible to construct a converter in such a way that the gas currents above the metal bath would not be so rapid.  Although the metal is very hot and liquid it is well to add some ferromanganese to be sure of absolutely quiet steel before casting.  The slag must, of course, be removed more carefully in casting over lip.  In the Evans-Wills converter it is raked out through a side hole in the detachable underpart.  In some operations with ordinary side-blow converters sand is shoveled in through the mouth of the turned down converter after the blow thus forming a tough slag as a cover, which does not follow the steel.  A dam with fire bricks is then formed and the steel is tapped through the lowest part of the mouth.

## HISTORICAL

The practical value of the historical part is to show what constructions are out-dated and hence should be avoided.  I say this, knowing that patents have been taken out and methods started which are simply reversions to antiquated systems.

In 1856 Sir Henry Bessemer made the first steel produced by blowing air through pig iron.  The priority was disputed some years ago by an American but the claim does not seem to have been sustained.  It has also been asserted that the process was in secret operation at Essen in Germany for some years before 1856.  The first converter was stationary, cylindrical, with radial side tuyères near and parallel to the bottom.  The pig metal was poured in through a hopper on the side.  The flame escaped through a central hole in the top.  Sir Henry Bessemer anticipated by patents many ideas which were afterward taken up by others as original.

The development of the process was soon afterwards transferred to Sweden and I have a description of the first converter

in that country. It had horizontal tuyères near the bottom inclined so as to give a rotary motion to the metal.

In 1863 a stationary converter was erected in America but later was abandoned. Soon afterwards the movable converters with bottom tuyères came into general use.

In 1879 the steel-making world was profoundly stirred by the Thomas Gilchrist process of dephosphorizing in basic lined converters. I then made the personal acquaintance of Mr. Sidney Thomas and he gave me two patent letters, in one of which he anticipated the construction given above of iron pipes projecting outside the lining. He asked me whether there were any stationary converters left in Sweden. The object of that question became apparent in 1882 when he had constructed a side-blow converter on elliptical rockers so as to make the motion easy. He then says that it can be so tilted that some of the tuyères are above the surface, thus burning the carbonic oxide gas inside the converter. The idea of doing this was, however, anticipated a few years before by some American bottom-blown converters being so inclined during part of blow that some of the tuyères were above the surface.

In 1884 Messrs. Clapp and Griffith received the stationary converters, such a plant being installed in Pittsburg. The novelties were a special arrangement to plug up the tuyères from outside and a side hole through which the slag could be removed. Great improvements, especially lower silicon in the steel, were promised but it has been shown that however much slag is drawn there always remains more than enough to raise the silicon in the steel should a reduction of silica take place, which is hardly probable in a preëminently oxidizing process. But oxide of iron is removed during the boiling period and by withdrawing the slag at an early stage the waste is therefore increased. As the claims of superior metal were not sustained and with all the inconveniences of stationary converters against them the Clapp-Griffith process was gradually abandoned in America.

All subsequent side-blow converters were movable on trunnions. The development in that direction has to a great extent been made by Frenchmen.

In 1884 Messrs. Walrand and Delattre built the first known converter of this kind at Stenay, near Paris. The first construction had tuyères on one side inclined downwards and slant-

ing so as to give a rotary motion according to the first Swedish principle above indicated. By this construction good steel castings were obtained.

In 1885 M. Robert, then manager of the Stenay Works, flattened the back, made the tuyères parallel to the bottom but slanting so as to give a rotary movement. They were also moved up close to the surface of the bath whereby enough gas escaped to burn the carbonic oxide. This gave good results and the process was practically conducted as above described.

In 1889 Alexander Tropenas built a Robert-Bessemer plant for Messrs. Berges in Paris. He gave up the process as too wasteful and moved to Sheffield where the firm of Edgar Allen & Co. in 1891-92 developed his process as above with slightly concave back, nearly parallel tuyères, and especially the upper row of combustion tuyères which is really the only novel patentable feature. The original Robert converters have gradually grown less in numbers in America and the prevailing construction is now Tropenas, as described above.

As above mentioned, steel castings can be made from bottom-blown converters, and some very good articles thus produced were exhibited at the World's Fair in Chicago, by the Solid Steel Co., Alliance, O. In order to better preserve the heat the bottom-blown converters are in some places made portable, either hanging in a crane or placed on wheels and the casting made direct from them. But it is obviously awkward to handle such a heavy weight and rather difficult to regulate the pouring exactly for each mold, as well as to keep away the slag.

I have only mentioned those converters that have been or are in actual use. There are several other inventions for the same purposes which are buried in the patent office. I have made a collection of some of these.

Looking back on the many devices it seems almost impossible to get any more improvements in the same direction patented. The idea of burning carbonic oxide inside the converter to increase the heat is about 25 years old and as above stated the first converter in 1856 had side tuyères. Practically all that has been done during that long period is the arrangement of the side tuyères and it is therefore rather strange that the progress has been so slow. The history shows the usual contests between patentees and the lack of consideration most in-

ventors show towards their predecessors who served for foundation for the progress and sacrificed money and time on the development.

We have been taken by so many surprises that it is impossible to tell what the future will bring. It seems to me that a part of the off-going heat could in some way be utilized to heat the blast, also that additions of ferro-silicon during the blow are not sufficiently tried. Some small converters are in use for melting pig iron for malleable castings and for brass, in which a flame generated by a spray of petroleum is used. Perhaps under certain circumstances some addition of heat in this shape during side-blows for steel making would be economical, thereby permitting a lower silicon pig iron. It is also possible that a small open-hearth tipping furnace may be invented for the same purpose as the side-blow converters, with facilities for raising the heat, and with lining refractory enough to withstand it.

In conclusion I may say that in very few years from now, there will probably be much more to be said on this subject.

## SOME PRACTICAL HINTS ON THE MANUFACTURE OF OPEN-HEARTH BASIC STEEL*

### By G. A. WILSON

THE author states that open-hearth furnaces are much alike in England. He favors four-port furnaces, they giving better results than the five-port furnaces (two gas and three air ports). His method of lining the hearth with dolomite he describes as follows:

The best result I have so far obtained has been by placing old channels, or anything similar, around the bath, leaving a space for the thickness required for the banks up to six inches above the slag line. My own style of doing this is to start the bottom of bank three feet six inches and finish off at the top with 18 inches. I then put a truck of coal, or as much as would keep a good fire all round the banks, burning for three days. Next put half an inch of chrome ore on top of the basic banks; next the silica lining; and then the roof. After this I have the furnace cleaned out; the channels, or whatever framing may have been

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*Read before the West of Scotland Iron and Steel Institute. Slightly abridged.

used in the ramming process, also removed. I then have the bottom rammed in the furnace. In doing this it is better to ram about nine inches, put the gas in, and get the furnace up to the proper pitch of heat, afterwards burning the remaining dolomite required to frame the bath.

I may say that when burning or fusing the dolomite it will be found a great advantage to use five per cent of finely-ground basic slag along with the dolomite, as it will cause it to fuse hard and solid. It will also tend to stop the bath from giving way, more especially if it has been carelessly burned on.

In all cases where you have the slightest doubt about the first hand not thoroughly carrying your instructions out with regard to careful burning of each " fettling," or coating of dolomite, finish the bottoms off by ramming, and then give it at least one whole week's gas before commencing to charge.

I will now describe a magnesite lining I have been using, and which is now generally recognized as *the* lining for a basic furnace; for most firms manufacturing basic steel now use it.

All our furnaces at the works of Messrs. Dorman, Long and Company, Limited (both Britannia and Clarence), are lined with magnesite bricks, manufactured in the Sheffield district. These bricks I mention particularly, because, being burned in the same manner as the silica brick, they are far superior to the foreign pressed brick. This is an expensive bath, I admit; but from the results obtained I find it is only a first cost, and will well repay the initial outlay.

I build the linings in the ordinary way with magnesite bricks to six inches above the slag line. I build the bottom nine inches thick at the tapping hole, tapering back to 16 or 18 inches along to the charging doors and blocks.

The mortar I use for setting the bricks is dead burned magnesite cement mixed with equal parts of hydrochloric acid and water. Next put gas in and burn the remainder of the bottom in with dolomite, as previously described.

The author also describes his method of charging the furnace and of conducting the operations.

Different classes of basic iron require somewhat different treatment. Taking the iron we have to use in the Cleveland district, which is composed of No. 4, or what is called forge and white iron, these we use in equal parts. (I am now speaking

of the cold charging process.) The analysis (average) of the above-named irons is as follows:

| FORGE. | WHITE. |
|---|---|
| Silicon.....1.25 per cent | Silicon.....0.90 per cent |
| Sulphur....0.20 per cent | Sulphur....0.35 per cent |
| Phosphorus.1.50 per cent | Phosphorus.1.50 per cent |

This, by using from 15 to 20 per cent of scrap, gives an analysis of just over one per cent of silicon and 0.2 per cent of sulphur. You will, therefore, note that it requires very careful treatment to successfully get rid of the sulphur and phosphorus.

In charging the furnace I first of all put in the whole of the scrap, next the limestone required — viz., 3½ cwt. per ton, and also the oxide — 1½ cwt. per ton, and lastly the pig iron. When this is melted we have a very thick slag, which we open out with three or four cwt. of calcium chloride or fluor spar and five or six cwt. of oxide (mill scale). And here I might say that mill scale is the steel smelter's "salvation" if rightly used. Of course I refer to scale which is free from silica sand, or contains at least not more than 4 per cent. In about 45 minutes from the opening-out part of the process, we take what is called the melting sample, and, as a rule, find the result is:

Carbon .....................0.8 to 1 per cent
Phosphorus .................0.3 to 1 per cent
Sulphur ....................0.08 or under

This is now where the skill is required by the leading hand on a furnace; because if he does not keep his slag in proper condition, so as to hold the carbon till he gets the result of the sulphur in the melting sample, he will allow the carbon to go, and very probably will not have got the sulphur down as low as required; and in that case he will find more difficulty in getting, say, the necessary two points to bring the sulphur under 0.06 per cent than if he had taken the precaution of "holding" his furnace till he got the result of the melting sample. If the sulphur is right, however, he will at once add more oxide (scale or mill cinder). Of course, other oxide may be used, such as Gellivara ore or mill cinder, to bring the carbon down; but, as I have said previously, it is here that mill scale comes to the rescue, because by feeding with this you will create the necessary amount of iron in the slag to make it basic — thereby getting rid of the phos-

phorus without bringing the carbon down to a point which causes you to have to " pig " back.

I would like to add a word here as to what I call a basic slag, because some think all that is required to eliminate the phosphorus is plenty of lime or limestone. To begin with, there must be plenty of lime or limestone to make a proper slag in the furnace; as otherwise there would be trouble when the metal was being run into the molds. A slag of proper composition is therefore of first importance to the smelter, as showing him to have what he terms generally plenty of heat for tapping, and in giving the manager satisfaction in the pit, both as regards the behavior of the steel in molds and also in not cutting the bricks in the ladles to pieces. But, as I have said, you may have this good slag and still find the old enemy phosphorus present. Now, this is because you have a limey slag, but not a basic slag; or, in other words, a slag with an insufficient amount of iron in it.

At this point scale is again of assistance; for by adding two or three cwt. to, say, a charge that is stuck with 0.1 per cent of phosphorus, you will almost invariably be quite satisfied after seeing the result of the next sample taken. I find in all cases where I have analyzed the slag and get a result of 48 to 51 per cent of lime, the silica down to 14 per cent or under, with 6.5 or more of iron, that the phosphorus is always 0.60 per cent or under.

For instance, taking the following samples from one of our furnaces — namely, the J, cast No. 57 — and taking the composition of the metal I described above, the melting sample was:

  C, 0.9 per cent; S, 0.092 per cent; P, 0.3 per cent.

Slag — Fe, 3.8 per cent; Silica, 16.4 per cent; Lime, 50.0 per cent.
  Second sample:

  C, 0.45 per cent; S, 0.064 per cent; P, 0.08 per cent.

Slag — Fe, 6.3 per cent; Silica, 13.9 per cent; Lime, 52.0 per cent.
  Third sample:

  C, 0.35 per cent; S, 0.058 per cent; P, 0.06 per cent.

Slag — Fe, 6.6 per cent; Silica, 13.7 per cent; Lime, 48.8 per cent.
  Fourth sample:

  C, 0.28 per cent; S, 0.05 per cent; P, 0.05 per cent.

Slag — Fe, 8.4 per cent; Silica, 12.4 per cent; Lime, 53.8 per cent.
  Fifth and tapping sample:

  C, 0.18 per cent; S, 0.046 per cent; P, 0.03 per cent.

Slag — Fe, 9.5 per cent; Silica, 11.9 per cent; Lime, 49.8 per cent.

The analysis of the steel from the casting pit was: C, 0.155 per cent; M, 0.435 per cent; Si, 0.004 per cent; S, 0.042 per cent; and P, 0.019 per cent.

Of course, operating on iron, where you have no sulphur to take into consideration, you can afford to considerably curtail the amount of limestone when charging the furnace, as you have plenty of time to get the slag into proper condition after the charge is melted and before the carbon gets away. By this method the speed of the furnaces is considerably increased.

I will now say a few words in connection with the direct or hot-metal process. As far as I am aware, we have three different systems at present in practice — namely, the Talbot continuous process, which is at work at the Frodingham Iron and Steel Company's works (and here I might say that I expect to start a 200-ton furnace at our place in the first week of the new year); the Bertrand-Thiel process at the Earl of Dudley's Round Oak works; and the direct process, in operation at our Clarence and Britannia works. In my opinion the direct process is the correct one; and I think I am not going beyond the mark in saying that steel makers who wish to " line up," as the Yankees say, will have to adopt it, if they want to keep abreast of the times. It is claimed for the Talbot process that it works very well at Frodingham. My own opinion is that if there is one place in the country where there is a chance to work it successfully it is at Frodingham, because undoubtedly they have the best and most suitable iron to deal with. Taking into consideration the class of iron we have in the Cleveland district, and from the information I have from Round Oak, I think the Bertrand-Thiel process is a very good one, and well worth the consideration of anyone who may be seriously thinking of adopting any of the direct processes. Personally, I have had no practical experience of the Talbot, and very little of the Bertrand-Thiel process. As regards our own direct process at Middlesborough, I am pleased to say that we are doing very well. At the Britannia works we have a mixer, with a capacity of 350 tons, and at the Clarence works one capable of holding about 250 tons. Both work by producer gas. I may be asked the question, " Why a mixer?" Well, in my mind it is everything; because you can then guarantee an almost uniform class of metal to the melting furnaces, and you are also in a position to " doctor " it in the mixer if you happen to be getting a " run " of.

inferior metal from the blast-furnaces. The metal comes from the blast-furnaces in 15-ton ladles, and is poured into the mixer. Oxide of iron and limestone are charged into the mixer to reduce the silicon in the metal to about 0.8 per cent; and we can also deal partly with the sulphur. At the Clarence works the metal from the mixer is then poured into 25-ton ladles and taken to the steel furnaces, where the ladle is lifted on a hydraulic lift and the metal poured down the spout into the furnace, which has been previously charged with ore and limestone sufficient to remove most of the silicon, carbon, and phosphorus. At the Britannia works the only difference is that we bring the metal from the mixer with the 75-ton overhead electric crane, which we also use in the casting pit. The metal as it comes from the mixer contains about 0.8 per cent of silicon, and on an average about 0.15 of sulphur.

# ABSTRACTS *

*(From recent articles of interest to the Iron and Steel Metallurgist)*

BLAST-FURNACE Gas as the Only Source of Power in Modern Steel Works. Karl Gruber. "Stahl und Eisen," January 1 and 15, 1904. 7,500 w. — The time seems now approaching when the waste-gas engine will entirely supersede the steam engine in iron works. It will be shown in this article that with economical use of the gas, iron and steel works can be run by gas engines alone. The firm of Klein Bros., in Dahlbruch, have a rolling train run by a gas engine, and Krupp in Essen tried the experiment of running a rolling mill of two trains with an illuminating gas engine with very satisfactory results. The establishment in which Gruber's experiments were made consisted of four blast-furnaces, each producing 300 tons daily, a basic Bessemer mill with four converters, each holding 18 tons of liquid pig iron, an open-hearth plant consisting of two 25-ton furnaces, a reversing blooming mill, a reversing finishing train for finishing heavy pieces of iron, three high mills for various smaller bars, and wire trains.

In order to have a basis on which to calculate the amount of gas produced in a blast-furnace, Gruber took 100 kg. of fuel for 100 kg. of pig iron smelted. In this case the amount of gas given off is 4,500 cubic meters per ton of iron produced. Half of this is used in heating the gas, so 2,250 cubic meters of gas are

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left for other purposes. With a better built heater and more economical use of the gas, less than half would be necessary for heating the blast. One cubic meter of furnace gas yields on the average 700 to 1,000 calories (aver. 900), so three cubic meters of gas can be reckoned on for one horse-power per hour. For every ton of iron then $\dfrac{2250}{24 \times 3} = 31.2$ horse-power. For working the various machines belonging to the blast-furnace, reckon 7.5 horse-power per ton of iron, which leaves 23.7 horse-power for other purposes, and with a daily production of 1,200 tons, gives $1,200 \times 23.7 = 28,400$ horse-power; $28,400 \times 3 \times 24 = 2,040,000$ cubic meters gas in 24 hours. In smelting minette ore, 110 kg. of coke, at least, are used for 100 kg. of iron, which produces 5,000 cubic meters gas per ton of pig iron, or 33,000 horse-power on a daily production of 1,200 tons. This power can be transferred from the blast-furnace to the other works.

The progress made in the methods of purifying gas allows for a successful working of motors. The dust content of waste gas varies from 12 to 45 grammes in a cubic meter. By modern methods the gas can be so purified as to be freer of dust than air. For the first coarse purifying of the gas as it comes from the furnace, the steam jet exhauster is used, which rids the gas of all but 0.2 g. per c. m. In this form the gas can be used for working the steam boiler, as for this purpose a gas purified to 0.3 g. is sufficiently pure. To work the motor, the gas must undergo a further purification, and for this is used the Differdingen method, which consists of two ventilators, one working behind the other, provided with water jets, or the Theisen centrifugal purifying apparatus. For a well-constructed gas motor a purification of 0.02 per c. m. is sufficient, yet it is desirable to purify to 0.01 g. The method of purifying with sawdust filters was used with the first blast-furnace gas motors, and is still in use in many iron works. It has the advantage that the dust content of the gas is reduced to 0.002 g., but the apparatus necessary is very costly. In the new establishments, then, the choice lay between the Differdingen and the Theisen methods. Both of these have been so improved that they purify to 0.01 g., and the Theisen may be made to purify to 0.005 g., which is very satisfactory.

The water content of the gas at a temperature of 150° may be 160 g. per c. m., but may also amount to 300 g. The various

washing contrivances used for purifying the gases, lower the temperature of the gas at the same time, and so diminish the water content, which may be as low as 2 g. per c. m., and in this proportion it does not impair the working of the motor.

The blast-furnace gas motor requires surplus gas, air, lubricating oil, and cooling water. The gas when purified is ready for use, the air is used without previous preparation. The use of lubricating oil varies in different works from 6.5 g. to 1.0 g. per horse-power per hour. The latter amount ought to be the average required by careful use on a well-constructed motor. The use of much cooling water causes difficulties in working motors. The amount varies from 40 to 80 liters per horse-power per hour, and for recooling a further use of from two to four liters is required. Besides this cooling water, more water is needed for purifying the gas. In the Differdingen process the amount of washing and cooling water is estimated at 4.7 liters per horse-power and per hour. But perhaps a smaller quantity would be sufficient. The loss of water by vaporization in the cooler is made up by the condensation of steam held in the hot water.

Five motor units of 500 horse-power each give the best result in large establishments. Four can be used and the fifth kept in reserve. An average of 1,000 horse-power is needed daily. The amount of electric power required for the blast furnaces is 250 horse-power on the average, so that 750 horse-power remains as the working force for the other works.

*Blowing engines for working the converters.* — A good blowing engine is able to begin work at full force as soon as turned on and to work with different blast pressures. These conditions can be fulfilled with an electric motor, if a series motor is chosen, for this allows of beginning work quickly and can be worked at different rates. But this is costly, for a primary gas engine and motor are required and a secondary motor and blast cylinder. This complexity makes derangement easy. It would be cheaper if the blast engine were connected directly with a gas motor. Reliability is attained by means of a reserve blast. The changes in working force are made possible if the motor is provided with a very delicate hand regulator. To satisfy the second condition, the motor must go slower during the pause between charges, so that at the beginning of the charge the motor can be set going again at full force. Working with a gas motor is cheaper than

either steam or electric motors. The blowing apparatus should be built for a working force of 3,000 horse-power, and taking the consumption of gas into account, this would give a daily power of 1,500 horse-power.

*Arrangement of the rolling mills.* — The blooming train and the reversing finishing train may be run by steam engines, by which means the steam is produced in the boilers heated by the waste gases. Steam power is chosen for this because the trains require swift reversing. All the other trains can be worked by gas motors, as they are provided with fly wheels, and the motor runs always in the same direction. Between the fly wheel and the rolling train is inserted a coupling which is coupled as soon as the motor wheel reaches its full number of turns. For this purpose the Schwarz friction coupling is most suitable.

There are three conditions to satisfy in the rolling mill. 1st. The reversing engine must be strong enough and the rolls must have such a diameter that heavy pressure can be put on and the pieces can be rolled out in a few turns. The advantage thus obtained is in time gained and in the fact that the blooms are very hot and can be finished off at the same heat. 2d. The rolls adjusting apparatus must work very quickly. 3d. The reversing of the rolling gear and the block turning and raising must be accomplished quickly and carefully.

The total working force of all the motors in the steel plant is given as 5,250 horse-power. Reckoning three cubic meters of gas per horse-power and hour would make the amount of gas used in 24 hours $3 \times 24 \times 5,250 = 378,000$ cubic meters. Adding to this the amount consumed in working the reversing and blooming trains (756,000), makes a total consumption of 1,134,000 cubic meters. As the working of the converter blowing engine and the various rolling machines varies so much and in consequence also the amount of gas consumed varies, it is necessary to have between the blast-furnaces and the places where the gas is used a regulator in the form of one large or several small gasometers. Gruber prefers the latter arrangement and would distribute the gasometers to correspond to the machines. The gasometers, too, would make the gas more uniform in quantity and composition.

*Reheating furnaces.* — As a basis for his reckonings, Gruber takes a gas composed as follows: 8.5 per cent $CO_2$, 0.71 per

cent O, 25.41 per cent CO, 4.31 per cent H, 0.3 per cent $C_2H_4$, and 60.77 per cent N, which yields a caloric value of 924 cal. The pyrometric value of 1,460° is reckoned under the supposition that gas and air have the ordinary temperature. Now in working the Siemens furnace, the gas and air are heated beforehand and so attain the temperature in the hearth chamber. It is assumed that the producer gases are heated in the regenerator to 850° and the combustion air to 950°, and that the surplus air amounts to 20 per cent. In this case a combustion temperature of 2,150° would be attained in the hearth, which is quite sufficient. If the rolling mills are joined to the steel works so that the ingots can be transferred immediately to the soaking pits, the latter need not be heated, and large pieces of iron can be rolled out without intermediate heating. Only for the larger shapes and for the smaller ones, and for rails is an intermediate heating necessary.

In an unfavorable case for the consumption of fuel, *i. e.*, in the case of heavy rails, for which an intermediate heating is necessary, being rolled out on the reversing train, the amount of heat necessary for this intermediate heating can be proportionately very small, as the bloom reaches the furnace while still very hot, provided that the transfer from the rolling train to the reheating furnace is made very quickly. In this case three per cent of fuel is sufficient, *i. e.*, 30 kg. of coal for a ton of rolled material.

*Open-hearth Plant.* — This should consist of two basic furnaces each holding 25 tons, which work up the Sunday pig iron and the shop scraps and produce daily about 150 tons of ingots. There is enough gas left and it has a high enough temperature for working the open-hearth furnaces. If 2.6 per cent of fuel is reckoned for the open-hearth furnace, for a production of 150 tons 39,000 kg. of coal or 253,500 cubic meters of gas are necessary. Then the total consumption of gas will be 1,826,250 cubic meters. As the blast-furnace produces 2,040,000 cubic meters of waste gas in 24 hours, 213,750 cubic meters are left, which will yield 3,000 horse-power. Most of the time the surplus gas is more, as the reheating furnaces are only used when the iron of larger section is to be rolled.

It is a great advantage for a mill to have its own coking establishment and have it near the steel mill. For in the production of coke, gas is evolved in such quantities that after a suita-

ble amount is used in heating the furnace, 40 per cent can be used for working the motors. The open-hearth furnace can be run advantageously with this coke gas, for it can be blown into the furnace directly without the use of a regenerator, and the regenerators are then needed only for air.

Condensing engines are much used to increase the usefulness of gas motors and have been very satisfactory. Carbon dioxide, ammonia and sulphurous acid are used as cooling and evaporating liquids. The sulphurous acid is used most and works the best. The problem of packing for the stuffing box has been well solved and the packing lasts as long as ordinary steam engines do. Sulphurous acid has a boiling-point at —10° C., and it is best to work with a pressure of 13 atmospheres. The condensation in the cylinder is very small because of the low temperature of the steam and the amount of sulphurous acid used is very small, provided that all the packings are tight. A good gas motor has a working efficiency of 23.6 per cent, which is double that of a very good steam engine. A closer investigation shows that a large part of the heat which escapes could be saved and the working efficiency nearly doubled if the heat which passes off with the cooling water and the gases could be used for the condensing engine.

In consequence of the gain in power in such an establishment as has been described, there would be 31,150 horse-power surplus which could be applied to other industrial undertakings in the form of power or light.

It is often claimed that the amount of water used with gas motors for cooling the motors and purifying the gases is too great and that, therefore, only those works can use gas motors which have a sufficient water supply. But modern steel plants already use such large quantities of water, that they will not need more water in the future when they are run by gas motors.

Blast furnaces in the future will serve not only for producing pig iron, but will furnish gas for the reheating furnaces; the open-hearth furnaces and iron-working engines will furnish power and heating gas for the whole establishment and surplus gas which will give power for other industrial purposes. **No. 93. Each C.**

**Strength and Structure of Cast Iron.** Oskar Leyde. "Stahl und Eisen," January 15, 1904. 4,500 w. — The tests

which are required by the various railroad managements, to be applied to cast iron used in the construction of locomotives, vary greatly. The purpose of this article is to show with what caution the results of the experiments are to be read, with what heterogeneous material one must reckon, and what allowances must be made with regard to the required strength. The strength of cast iron depends, in the case of uniform material cast from the same ladle, on the size of the piece or of its separate parts, i.e., on its rate of cooling, since, if the various parts are cooled quickly or slowly according to their thickness, they have more or less opportunity for forming larger crystals, for "coarser structure," for the separation of graphite, and they will have throughout various degrees of strength. They are usually less strong than the test bars, for the test bars are usually of smaller dimensions and cool more quickly and so are finer grained. So it is only with great reservation that one can judge of the strength of the various parts from the strength of the test pieces.

This fact is little known or recognized, as is shown by a requisition of a railway management for the construction of hydraulic machines. There was to be one bar tested for each of the various castings needed. These bars were to be cast with the other castings, worked out according to draught, and to show a breaking strength of 13 kg. per sq. mm. The various models differed greatly in dimensions, so the testing bars were in some cases three times as weak, in others three times as strong, as the castings; some of them were much looser and weaker, and others were much sounder and more compact, than the corresponding castings. The tables given show these variations and show also how the strength of the inner part of the castings diminishes when the cooling of the outer shell of the casting takes place more quickly in the wet sand mold than in the dry mold. Different size castings were made of iron containing respectively 2.1 per cent, 1.5 per cent and 1.2 per cent silica. Aside from this the irons were about of the same composition; three per cent carbon, 0.6 per cent phosphorus, 0.7 per cent manganese, and about 0.12 per cent of sulphur. The tables show the results of the tests. The broken surfaces showed that the different pieces had the desired grain corresponding to their dimensions, but on the contrary, the thinnest bars, when broken in halves, were

almost white, and the thick bars were too coarse in structure. This is not new to the expert.

At the request of the author similar tests were made in the interest of science at the technical mechanical laboratory at Lichterfeld, with the help of the powerful testing machines there, and tables showing their results are given. With the softest iron it is seen that the thinnest bars of 10 mm. $\times$ 10 mm. have a tensile strength of 47 kg., while the largest bars, measuring 150 $\times$ 150 mm., had a strength of 18 kg. per sq. mm. This shows how much the strength varies in different parts of one and the same piece of casting, as well as in a testing bar cast at the same time with it. It shows also how inadequate the tests are to ascertain the quality of the castings, if the sizes of the castings are not taken into consideration. It shows also what great allowances must be made in the requisitions, if the castings are to be judged by the test bars.

On the causes of this phenomenon, that under like conditions and with like mixtures of iron the smaller bars, i.e., the more quickly cooled, are so much stronger than the larger, more slowly cooled bars, the author refers to a report, made September 5, 1903, at Rubeland at the fifth general meeting of the German Association for the Testing of Materials, which throws some light on this question from a metallographic point of view. But some explanation can also be given through chemistry. At the request of the author, Professor Heyn made a microscopic examination of a series of test bars. The quantitative increase of graphite in the larger bars appeared small; but it is to be assumed that the strength of the iron is influenced more by the disposition and size of the graphite particles than by the quantity of graphite formed, as well as by the size and distribution of the iron crystals. **No. 94.  C.**

**The Electric Smelting of Iron and Steel.** " The Iron and Coal Trades Review," January 15, 1904. 4,100 w. — We reproduce below the introductory remarks of this paper:

" Much attention is now being devoted to the problem of steel production in the electric furnace, and electro-metallurgists are devoting attention to this new and interesting application of the electro current as a heating agent. The

aim of these investigators is to design a furnace and process which will permit of the reduction of the ore and of the direct production of steel, or of any desired alloy of iron with nickel, chromium, manganese, etc., in one or at most two operations, without any use of carbon, beyond that required for the actual combination with the oxygen of the ferric oxide present in the ore. Electricity is, therefore, to take the place of gas or coke used for heating purposes in the ordinary blast-furnace process. The solution of this problem is no easy task; for the electric furnace is not an economical heating appliance, when large masses of material have to be dealt with; and the ordinary blast-furnace with which it is to compete is an economical and efficient appliance for the utilization of the energy of fuel when the waste gas is fully utilized. Owing to the large mass of material to be heated, the most efficient method of applying the electric current, namely, arc-heating, is beset with special difficulties. Should this method of heating be applied, a preliminary grinding and mixing of the ore with the coke and flux will be necessary — for only small portions of this mixture can be brought under the action of the arc at any one moment of time. This preliminary treatment will be expensive, and is likely to add a very large percentage to the actual cost of the whole process of smelting in the electric furnace. Electric resistance furnaces, designed on the blast-furnace principle, into which the ore, lime, and coke are charged in the lump condition, and in which the necessary mixture of the raw materials is effected by gravitation as the half-molten charge slips toward the throat of the furnace, would consequently appear to offer the greatest advantages, since the costly grinding and mixing of the charges could in this case be dispensed with. Both types of furnaces — namely, the arc and the resistance furnace — have been experimented upon. In the following table are enumerated the principal processes of manufacturing steel electrically, with the names of the inventors, the types of furnace employed, together with sundry other details. The dates given refer to the time of publication or of the issue of the patent, and are of no importance in regard to the question of priority of invention or successful application in practice. Dr. Heroult, as early as December 28, 1900, smelted by means of electricity at his works

at Froges, for the first time, a quantity of steel weighing eight tons 18 cwt., which he delivered to the firm of Schneider & Company, at Creusot, in bars 960 lbs. in weight. Further particulars are given in his patent specifications with regard to the construction of the furnace, but relatively very little is to be gathered from them bearing upon the method of working.

*Processes Introduced for the Production of Steel by Electricity.*

| Process | Date | Type of Furnace | Materials Employed | Consumption of power per ton of steel in horse power hours | Cost per ton of Steel in Shillings |
|---|---|---|---|---|---|
| Gin-Leleux | 1897 | With carbon electrodes | Pig iron and scrap | —— | —— |
| Stassano | 1898 | With carbon electrodes 500 h. p. | Very rich Italian iron ores | 38,004,000 | 90 |
| Gysinge (Crucible Steel Process) | 1900 | Without carbon electrodes 225 h. p. | Pig iron and wrought iron | 1,320 | 172 |
| Froges Heroult | 1901 | With carbon electrodes 400 h. p. | Pig iron and scrap | 1,200 | —— |
| Keller | 1901 | With carbon electrodes 1,200 h. p. | Iron ores and pig iron | 3,800 | 72-80 |
| Harmet | 1901 | With carbon electrodes | Iron ores | 3,600 | 24 (not the total cost) |
| Schneider | 1901 | Without carbon electrodes | —— | —— | —— |
| Ruthenberg | 1901 | With carbon electrodes | Iron ores | —— | —— |
| Conley | 1902 | With carbon electrodes | Iron ores, pig iron and scrap | 1,000 1,042 | 48 114 |

The figures given above for the consumption of power and cost per ton must be taken with great reserve. They are only the inventors' claims, and are open, in some cases, to serious doubt, if not disproof. They are merely introduced here to show the great variation in the claims of different inventors.

The author reviews these various processes at some

length, giving illustrations of the furnaces used, and he concludes that the conditions under which the actual manufacture of iron and steel may be profitably carried on by electric methods are so rare that they may be said to be practically not-existent. **No. 95. B.**

**On the Action of Limestone in Iron Cupolas.** F. Wüst. "Stahl und Eisen," January 1, 1904. 3,000 w. — The amount of limestone used in melting pig iron varies from ten per cent to 35 per cent. The purpose of the limestone is to scorify the coke ash, forming a slag readily removed from the furnace. So the amount to be used depends on the amount of ashes in the coke and also on the composition of the limestone itself. The purer the limestone, i.e., the more carbonate of lime it contains, the larger the amount of ashes it will scorify. The presence of silica and clay in the limestone will hold a certain amount of lime in combination so that a larger per cent of lime to the amount of ashes will be needed. Limestone is also used to prevent the iron from absorbing the sulphur in the coke, for sulphur is injurious to the castings. Experiments have been made by Sulzer Brothers at Winterthur under the direction of Sulzer Grossman and his engineer. Eleven experiments were made with the quantity of limestone increasing till in the last it was 33½ per cent of the mixture. The slag was collected on the fore hearth and at the close of each experiment run off into a sand bed, the quantity determined, and an average piece tested and analyzed. A chemical analysis was also made of the liquid pig iron at the same time. Test bars were made and tested for ductility, deflection and malleability. The greatest differences were found in the content of silica, while the content of phosphorus and manganese varied only a little. This shows how difficult it is to get castings of the same composition at different times from the same mixture. Manganese is present only in small quantities, and so is not much affected by oxidation, but silica is chiefly affected by it, a fact which partly explains the decrease in silica in the various smeltings.

The limestone does not affect the content of manganese and silica, as the experiments showed; but the content of sulphur fell from 15.6 per cent to 8.5 per cent with the increase

in the amount of limestone. The slags tested showed the following qualities: The first three were viscid and somewhat frothy, the next two were liquid and after cooling not so brittle as the previous ones, the rest were all liquid and after cooling were strong and hard. The color of the slags began with light brownish green for the first one and became gradually darker, and finally in the last one, black. In all the tests the content of alumina showed the greatest variations. That is explained by the fact that in different working of a furnace the lining is not equally attacked. There is a striking change in the content of sulphur. It is theoretically correct to assume that the slag of a cupola furnace must be capable of absorbing more sulphur, the more limestone, manganese oxide, and iron oxide it contains. In general the sulphur content of the slag should have increased with the decrease in silica. But the results of the experiments show that the conditions are not so simple. The analyses do not show that the presence and action of manganese oxide increase the power of the slag to retain the sulphur; the temperature of the slag and its degree of fluidity have an important effect. The higher the temperature and the more liquid the slag, the greater the capability of the slag to absorb the sulphur. By the experiments made to show the amount of waste in relation to the quantity of admixtures, it was shown that the amount of waste commonly estimated in text books is too high. Ledebur figures it at from three per cent to six per cent, while these experiments show it to be from 0.8 per cent to 1.6 per cent. It is to be noted here that the increase in sulphur, which varies from 0.17 per cent to 0.02 per cent in these experiments, is not considered at all in these estimates. Likewise the content of iron in the slag is disregarded. But the amount of iron in the slag would reduce the waste about 0.1 per cent.

The conduct of carbon in the smelting process has a greater influence on the waste. It decreases if the mixture is rich in carbon, and the melted material can absorb carbon from the fuel before its saturation point for this substance is reached. This is the case when iron scrap is present in considerable quantities in the mixture.

The testing of the iron bars gave the following results: The ductility increases till the proportion of limestone reaches

one-fifth of the amount of coke, then it is not further affected. The malleability was similarly affected. The ductility was increased as the amount of limestone increased. The deflection and elasticity were not appreciably influenced by the admixture of limestone. **No. 96. C.**

**The Widening Use of Steel Castings in the United States.** W. P. Barba. "Cassier's Magazine," February, 1904. 3,900 w. — The author describes some of the more important and newer uses of steel castings. The following paragraphs extracted from this article are of especial interest :

"The severe physical requirements asked are further proof of the trust reposed in steel castings as modernly produced. What engineer, for instance, would ten years ago have allowed, if he knew it, to be placed in his structure steel castings designed for a tensile strength of 80,000 pounds? All the specifications then called for steel of 60,000 pounds and stretches as low as 12 or 15 per cent, and any one who offered steel as high as 80,000 pounds tensile strength would probably have had his castings rejected. And yet today manufacturers are turning out steel castings where the minimum physical requirements are — tensile strength, 80,000; elastic limit, 40,000; extension in 2 inches, 18 per cent. The tendency in specifications now seems to be to higher requirements — higher carbons, and then intelligently directed heat treatment as the last operation before use.

"Engineers are no longer afraid of the harder steels. The development of the art offers every assurance of good and correctly handled product, and the subsequent annealing, always provided by the careful manufacturer who studies the individual uses of his output, whether such annealing be ordered by the purchaser or not, has given designers far more confidence in steel castings than has ever been enjoyed before. That this confidence is not in any way misplaced, the instances of modern use of steel castings to be hereafter set forth will serve to indicate.

"To speak further of the harder steels necessarily brings up the question of the new high-speed tool steels, without which the harder steels would meet with much opposition in the machine shops because of the slow progress in machining.

Even on the ordinary softer castings, as more generally furnished, the cry is raised by the machinists that " they cut hard," while with the self-hardening tool steel properly handled, as is now so well understood, this complaint is seldom heard.

" This matter of high-speed tool steels is responsible for one of the newer uses of steel castings, in that the old machine tools, when driven hard, removing far more metal per hour than was ever dreamed of when their design was put forth, cannot stand the strain, and are giving way in every direction. First one part is strengthened by the substitution of a steel casting for the iron primarily used: this part transmits its increased load easily to the next, and that breaks down in its turn, with consequent replacement with steel, and so on — the old story of every repair job under increased pressure of operation. Then the builders of machine tools redesign their machines, perhaps allowing more weight in the cast iron parts, but certainly replacing many of them with steel castings, thus giving at first the maximum stability to their designs.

" Another example of this enforced substitution of steel castings for iron castings may be found in the framing of steam hammers, both large and small.

" The heaviest steel castings — not the largest — thus far made in America were recently finished, being the top and bottom and heads of a great forging press, and weighing upwards of 200,000 pounds per casting. The largest, 33 feet by 16 feet by 50 inches deep, weighing 165,000 pounds, has just been made, and is one of two chassis girders for the mounting on a disappearing carriage of the 16-inch gun recently sent to Sandy Hook. The gun is mounted in the upper jaws. The whole carriage, when finished, will contain no less than 1,100,000 pounds of steel castings, and would be an entirely impossible construction were it not for the facility with which such dependable steel castings are now being produced.

" A word, now, as to the securing by the consumer of the casting best suited to his needs. It is not enough to simply get a price and ship the pattern and expect to receive in return the exact thing desired: a little consultation with the manufacturer before making the finished design, or a letter or two passing between maker and user before placing the order for

the pattern, and there would be received in return, cheerfully furnished, the advice and the experience of men whose sole business it is to produce an article whose use is comparatively infrequent with the purchaser. In all cases the drawing should be sent to the foundry with the pattern, so that a further inspection and check of the pattern may be made and the rough casting be inspected for finish and dimension before shipment to the consumer.

" The above simple procedure would benefit the consumer to a degree not realized by one who has not followed it, and would prevent many vexations frequently resulting from carelessly made patterns — too often made in an outside pattern shop, and not checked by the designers. This system has been practiced by the writer for ten years with entire success, and it cannot be too strongly urged upon users of steel castings to take the maker a little more into their confidence in the design primarily, and, so far as may be done, in the use of the piece desired. Failures and too short a life of parts often follow neglect of these recommendations." **No. 97. B.**

**Gas in Pig Iron.** E. Munker. " Stahl und Eisen," January 1, 1904. 3,000 w. — Munker gives the results of his tests of gas in the pig iron from two different furnaces working under different conditions; one of 385 cubic meters contents with a blast temperature of 800° to 900° from Cowper stoves, and the other of 80 cubic meters contents with a blast temperature of 450° from iron pipe heaters.

The chemical composition of the pig iron is not the only factor to be considered. The absorbing power and the secreting power of the iron must be distinguished. The presence of a tenth or a hundredth part of this or that element will not determine the quality and quantity of the gas evolved. The pressure in the hearth, the greater or less overheating of the iron in the hearth, the per cent of silicizing material, the fusibility of the slag, and the moisture of the blast all have their effect upon the gas.

The moisture in the blast current influences the hydrogen content of the liquid pig iron, as is shown by the analyses given in this article. The quality and quantity of the gases generated from liquid pig iron are perhaps to be decided from

other than purely chemical viewpoints, and, in accordance with Munker's experiments, on the following lines:

When the pig iron was poured out for the purpose of making tests it was divided into three grades: foundry iron, in a viscid state, puddling, steel, and spiegel iron, in a liquid state, and iron for rolls in a very liquid state. These were separated according to their degree of fluidity and analyzed. The casting iron contained much silicon, so it appeared at first as if this might have hindered the giving off of hydrogen. But the cast iron for rolls had a large silicon content, yet the evolution of hydrogen was almost eight times as great. The same was true of the highly silicious gray puddling iron. The cast iron for rolls contains several hundredths parts of manganese, which should aid the evolution of hydrogen. But if manganese alone were sufficient for that, the spiegeleisen, which has the highest content of manganese, ought to generate the most hydrogen. But this is not the case. As the carbon content is about the same for all the kinds of pig iron tested, it, as well as phosphorus, sulphur and copper, does not play an important part in the elimination of gas. The quantity of gas eliminated would seem to be a function of the degree of fluidity. The more liquid the pig iron in the ladle, the better opportunity is given for the escape of the absorbed gases. Now if the pig iron is viscid and less gas is generated, the influence of the atmospheric air which cannot be prevented when the iron flows out of the furnace is more noticeable on this pig iron than on more liquid iron. Silicon and manganese exercise a certain influence on the evolution of the gas, as silicon makes foundry iron viscid by its well known effects on the carbon content, and manganese makes the iron liquid. But there may be other influences in the blast-furnace working which will make the iron viscid or liquid. The blast-furnace worker cannot depend much on the worth of analyses in practice. The influence of quality of the tested irons by the evolution of gas cannot be proven. The same may be the case with the gases which remain in the cooled solid pig iron. Tests were made of the gases found in hard iron.

The amount of gas found was large. The best foundry iron in general contains more gas enclosed. Its viscidity may be the cause of this. A lessening of the moisture in the blast,

which under certain conditions reaches a fixed amount, caused, it appeared, a decrease in the bubbles in casting iron, but in iron for rolls there was always less gas under the same conditions.

It may be imagined that the residuum of gas in the pig iron smelted in small furnaces with lower blast temperatures is less than in the iron from the furnaces almost five times as large with the blast temperature higher and a larger quantity of air. No good reason has yet been found which will answer the question why the pig iron smelted in smaller furnaces is better for many purposes than that from the larger. **No. 98. C.**

**The German Iron and Steel Industry in 1903.** " The Iron Age," January 28, 1904. 1,500 w. — During the year 1903 the German iron and steel industry was chiefly affected by the renewal and extension of the syndicates. As was reported in October last, a number of these syndicates were renewed on a broader basis, but the great German steel syndicate is still the subject of negotiations, and it is quite impossible to state whether it will be finally brought about or not. This syndicate is to embrace the entire steel production — the greater part of the products like billets, beams, track material, plates, wire, etc. These are to be handled by central selling bureaus, and it was the plan to take up at once further products, and more particularly bars.

The employment of the German iron industry was very ample during the whole of the year in consequence of the very heavy export and the large increase in the home consumption. The production of pig iron was greater than ever before, having attained during the first 11 months of 1903, 9,236,886 tons as compared with 7,648,665 tons in the first 11 months of 1902. For the first time the annual production attains a total of 10,000,000 tons, as compared with 8,400,000 in 1902, and 5,000,000 in 1893.

Although the exports increased, as compared with the previous year, to the extent of about $7\frac{1}{2}$ per cent, this does not bear any close relation to the production of pig iron, which expanded to the extent of 20 per cent. It proves, however, in a most striking manner, how greatly the home consumption has developed during the past year.

Tables are given showing the production in various districts, prices for the home market on a number of the leading products, financial results of German stock companies as well as imports and exports of various iron and steel articles. **No. 99.   A.**

**Conditions Governing the Production of Steam Metal Alloys.**   Percy Longmuir.   " Feilden's Magazine," November and December, 1903.   6,200 w. — The author discusses the influence of certain conditions on the manufacture of steam metal alloys, in the following order : —

1.   The purity of the metals employed.
2.   The initial casting temperature of the alloy.
3.   The preparation of the mould including the method of gating, the size of the gate, the rate of pouring, and the disposition of chaplets or studs.
4.   The method of melting, including the length of time to which the alloy after becoming molten has remained in the furnace.
5.   The presence of oxide, dross, or mechanically held foreign matter, such as cinder, sand, and so forth.
6.   The presence of blow holes, cold shuts, etc.
7.   Shrinkage cracks or unequal shrinkage.

The microstructure of these metals is described, as well as its bearing upon the physical properties.   **No. 100.   Each B.**

**The Physical Structure of Metals and Alloys.**   J. J. Kessler, Jr.   " Journal of the Association of Engineering Societies," December, 1903.   Ill.   2,540 w. — The author describes in a brief and general way the microstructure and constitution of pure metals, of industrial metals and alloys, as well as the effect of strains on the structure.   He refers to the usefulness of the microscope in ascertaining the most desirable annealing condition for steel castings and for sheet electrical steel containing 0.07 per cent of carbon.   " It has been found," the author writes, " that the lowest hysteresis is found in steel which contains the best-developed crystalline grains, and these are developed only when the steel has been subjected to a definite heat treatment.   There are only two instances of a large number of cases in which the microscope has been found to be useful in studying the physical structure of metals and alloys, a feature which is becoming recognized as being

of quite as much importance to the knowledge and control of these materials as is chemical composition." **No. 101. B.**

**Machine Tools and High Speed Steel.** J. A. Carney. Paper read at the December, 1903, meeting of the Western Railway Club. 1,150 w. — A practical paper on the use of high speed steel in machine shops. The author concludes as follows: "The output of the shop equipped with old tools can be increased to a considerable extent by speeding up the machinery; but the makers of machine tools have had to wake up to the fact that heavier and more powerful machines must be made to keep up with the working capacity of high speed steel, and I venture to prophesy that heavy machinery is as yet in its infancy." **No. 102. A.**

**The Electrical Manufacture of Steel. Process of Gustav Gin.** P. McN. Bennie. "Electro Chemical Industry," January, 1904. Ill. 6,175 w. — Describes a new process which has so far been tried only experimentally. It involves the heating of a thin stream of metal by the passage of an electric current. **No. 103. B.**

**Testing of Metals by Means of Notched Bars.** M. B. Charpy (International Association for Testing Materials, Congress, Budapest, 1901). "Baumaterialienkunde," October 1 and 15, November 1 and 15, and December 1 and 15. 5,350 w. — An exhaustive and critical review of this new departure in the testing of metals. **No. 104. Each B.**

**The Blast-Furnace Gas Engine Plant of the Kladno Iron Works.** Karl Machacek. "Zeitschrift des Oestereichischen Ingenieur und Architekten-Vereins, November 20, 1903. 4,000 w. **No. 105. C.**

**Estimating the Value of Coke for Foundry Use.** Walter J. May. "Practical Engineer," December 4, 1903. 1,200 w. **No. 106. B.**

**Manufacture of Steel Pipe.** "Scientific American," December 12, 1903. 2,000 w. — An illustrated description of the manufacture of steel pipes at the National Tube Works. **No. 107. A.**

**Gun Steel and Armor Plate.** " Scientific American," December 12, 1903. 3,000 w. — An illustrated description of the works of the Bethlehem Steel Company. **No. 108. A.**

**The Manufacture of Steel Rails.** " Scientific American," December 12, 1903. 2,300 w. — An illustrated description of the manufacture of steel rails at the Edgar Thompson Works. **No. 109. A.**

**Composition of Slag in the Production of Ferro-manganese.** F. Wittmann. " Stahl und Eisen," January 1, 1904. 1,500 w. **No. 110. C.**

**Universal Rolling Mills of the Burbacher Foundry.** " Stahl und Eisen," January 1, 1904. Ill. 800 w. **No. 111. C.**

**The Manufacture of Iron and Steel Rails in Western Pennsylvania.** James M. Swank. " The Pennsylvania Magazine of History and Biography," January, 1904. 4,320 w. — An historical sketch of the manufacture of steel rails in Western Pennsylvania from its origin in 1841 to the present day. **No. 112. F.**

**The Modern Blast-Furnace.** A. Humboldt Sexton. " The Engineering Review," January, 1904. 2,900 w. — A short description of the development of the blast-furnace from the massive stone construction of 1830 to the modern type. **No. 113. B.**

**Heavy Foundry Work.** " The Iron Trade Review," January 21, 1904. 1,200 w. — Describes the making of an 85-ton casting, which is the bed of a reversing engine for the Lackawanna Steel Co., by the William Tod Co., of Youngstown, O. **No. 114. A.**

**The Platz Method of Calculating Furnace Burdens.** J. B. Nau. " Iron Age," January 28, 1904. 3,100 w. — A full discussion, with examples, of the Platz method of calculating furnace burdens now generally followed by German blast-furnace managers. **No. 115. A.**

**A Modern Jobbing Foundry.** " The Foundry," February, 1904. 1,800 w. — A full illustrated description of the Buffalo Foundry Company of Buffalo, N. Y. **No. 116. A.**

**Conditions Which Surround the Iron Producer in the United States and Great Britain Compared.** G. H. Hull. " Iron Age," January 28 and February 4, 1904. 7,050 w. — An able and critical review of the warrant systems in the United States and in Great Britain. **No. 117. Each A.**

**Basic Open-Hearth Steel Castings.** L. L. Knox. Read before the Pittsburg Foundrymen's Association February 1, 1904. Published in the " Iron Trade Review," February 4, 1904. 2,200 w. — The author gives the following figures for the production of acid and basic open-hearth steel castings:

|        | 1901          | 1902          |
|--------|---------------|---------------|
| Acid   | 206,681 tons  | 255,475 tons  |
| Basic  | 94,941 tons   | 112,404 tons  |

He then describes briefly the construction of an open-hearth furnace and the conduct of the process. **No. 118. A.**

**The Minnequa Works of the Colorado Fuel and Iron Co.** " Iron and Coal Trades Review," January 29, 1904. 6,700 w. — An illustrated description of the Minnequa Works of the Colorado Fuel and Iron Co. at Pueblo, Colorado. **No. 119. B.**

# EDITORIAL COMMENT

**The Industrial Importance of the Thermal Critical Points of Steel** It was discovered by Gore many years ago that when a highly-heated piece of steel is allowed to cool slowly, a sudden evolution of heat takes place at a certain temperature, causing a retardation in the rate of cooling, or even, under favorable conditions an actual rise of the sensible temperature of the metal — a recalescence of the cooling steel. This remained for many years the extent of our knowledge of this curious and unique phenomenon. The masterly investigations begun by Osmond some twenty years ago and followed since by many other scientists and metallurgists have added enormously to our information regarding the occurrence and meaning of the critical points of steel. Let us recall in passing that were it not for the timely invention of the Le Chatelier pyrometer, these investigations could not have been conducted — at least not with the same degree of success. To this distinguished engineer the metallurgical world owes a debt of gratitude.

Hardly a decade has passed, however, since metallurgists have realized that the determination of these critical points of steel had more than a laboratory interest, that they were of vital importance in dealing with the treatment of the metal. We find conclusive evidence of this recognition in a paper published elsewhere in this issue, written by Mr. Saladin, describing the method used at the great French steel works of Le Creusot. We are confident that this extremely interesting contribution will receive from our readers the attention it deserves, and that metallurgists will feel indebted to the management of this company for their generous publication of such useful information. The application, which the article records, of sound scientific methods to industrial pursuits is greatly to the credit of the management. Researches of an apparently exclusively scientific interest are too often looked upon by so-called practical men as mere laboratory

feats of little, if any, importance to them. They lose sight of the fact that all metallurgical progress must necessarily proceed from scientific progress, that the art of metallurgy is based upon the science of metallurgy; unless the latter advances, the former also must remain stationary.

Messrs. Schneider & Co., have been pioneers in the adoption of scientific methods, and they have reaped the rich reward to which such policy entitled them. Many improvements of commercially recognized importance are to be traced to their progressiveness, amongst which it will suffice to name the application of nickel steel to the manufacture of armor plates, which originated at the Creusot works.

**Possible Complications in Lake Superior Ore** — The problem which the Lake Superior ore producers have before them at present, in the matter of formulating their season program, is probably the most serious they have yet had to face. At the end of four seasons, during which a high and very profitable price has prevailed, there are heavy stocks at lower lake ports and furnaces, pointing to a very light mining season this year, yet some producers, on account of onerous lease provisions, will be forced to mine nearly their normal quantity of ore. The wide range in physical structure of Mesabi ores presents serious difficulties of its own, the screen test recently introduced not having worked to the satisfaction of all. The increased demand for Lake Superior ores in the past few years, and the partial working out of the purest and best deposits of the region, or their absorption by the United States Steel Corporation and consequent withdrawal of such ores from the open market, have forced the exploitation of lower grade deposits, and the system of fixing prices according to iron content which has hitherto prevailed works a disadvantage to the producers of such lower grade ores. Again, the lower phosphorus ores have been largely taken out of the market and it is more difficult for the independent furnace operator to purchase a good group of ores to make standard Bessemer iron. On the heels of these embarassments comes the proposal that the prospective poor season for Lake Superior ores be improved by extending the geographical limits within which it is feasible to use them. This means either a much lower base price at lower lake ports, or an absorption by

the ore producer of a large part of the rail freight from docks to furnaces not heretofore tributary to the Lake Superior ore supply.

The individual furnace operator has a greater interest in the subject of ore than ever before. A few years ago the ores offered in the market were all so rich that the differentials were of little importance. According to the system which has prevailed, the furnace pays for Lake Superior ores in proportion to the units of iron content. The richest ores do not furnish the requisite volume or fluidity of slag, and the employment of a certain percentage of less rich ores is necessary. On account of the exploitation of leaner deposits, the ores now offered contain an aggregate of impurities greater than slag considerations dictate. To use these leaner ores requires that the furnace operator pay freight on the extra impurities — against which the ore association makes a slight concession, equal to paying such freight only to the amount of 60 cents a ton — and pay for the extra coke and limestone required.

Now the unfortunate part of this situation, from the viewpoint of the maintenance of the Lake Superior Ore Association, is that in general it is the newer ore producers whose ore is thus discriminated against on account of its comparative leanness, who are under the greatest business necessity of operating their mines this year. They have lately acquired the properties, and in many cases at high royalties per ton, with a large minimum per year. They cannot go down into their pockets and pay these minima: they must mine the tonnage of ore to provide the cash. Yet it is their ores which would find the least ready sale in a season like the one forthcoming. The older firms, on the other hand, who could afford to lay back for a season, are the ones whose ores would be bought in preference, in a season where all could not be given orders enough to keep them running moderately full.

Again, the proposition to court the use of Lake Superior ores by furnaces at such a distance from lake ports that they have not lately used such ores, would, without a change in the general system of grading ores, result in such far-off furnaces purchasing some very pure ores to mix with their lean and nearby ores. This would defeat its own purpose, since the integrity of the association requires that the miners of the leaner lake ores shall have the demand for their ores fostered. This latter would require that

the leaner ores, having a heavy freight to pay, should be charged for at a considerably lower price per unit of iron, and this is not done with the present system of grading.

Altogether, the situation is one of the most serious difficulty, and the disruption of the Lake Superior Ore Association is far from improbable. This would mean a drop in ore prices possibly equal to 40 or 45 per cent of last season's rate, say for best old-range Bessemers from eight cents down to five cents per unit, and a reduction in the cost of making pig iron of from $2.00 to $3.00 per ton, or to exceed $3.00 in the cost of making a ton of finished steel.

The ore association held its first meeting on the subject of 1904 conditions and prices on February 5, and it may well be the end of March before the matter is settled in one way or another. The general desire of the members of the association is to make but a slight reduction from the prices of last season.

# CORRESPONDENCE

## Abnormal Structure of Brass

*To the Editor:*

Sir. — In reference to the letter and microphotograph of Mr. J. W. Varley, in the January, 1904, number of *The Iron and Steel Metallurgist,* the piece of cartridge brass has evidently been considerably overheated or burnt during annealing. It has every appearance of having been heated to a temperature of about 850° C., which would cause it to have the abnormal structure. Brass sheets containing 70 per cent copper should be annealed at about 650° C. for three hours, and on no account should the temperature exceed 750° C. The best etching reagent for brass is one part of strong ammonia diluted with three parts of water. Put 5 c.c. in a small glass or porcelain dish, add 1 c.c. hydrogen peroxide (20-volume strength), put in the specimen and keep it moving about for five seconds, remove the specimen, wash well in water, dip in alcohol, dry and examine under the microscope. The etching should be repeated, if it is not sufficient. I find this method of etching to be superior to the electrolytic or nitric acid method for brass.     , Ernest A. Lewis.

Birmingham, England, January 26, 1904.

## Influence of Structure Upon Strength Under Sudden Stresses

*To the Editor:*

Sir. — Strength under impact is one of the most essential qualities of metal for general railroad requirements. In some cases the results of the ordinary tensile tests give correct indications regarding these properties, but at times such results are very misleading, and tend to conclusions which are not borne out by subsequent service of the material.

As an instance of this general type we may cite the case of a driving-wheel tire, which fractured in service while in apparent good condition as to size and extent of wear and without any indi-

cations of internal flaws.  Upon analysis, we found the following composition, viz.:

Carbon ......................... 0.539 per cent
Phosphorus ..................... 0.052 per cent
Manganese ...................... 0.781 per cent
Sulphur ........................ 0.032 per cent
Silicon ........................ 0.254 per cent

The above gives no indication of weakness, nor do the tensile results which follow:

Tensile strength ..... 111,630 lbs. per square inch
Elongation in two inches.......... 17½ per cent
Contraction of area............... 44½ per cent

Upon cutting a section from the center of the tire, and polishing and etching, we found the excessively coarse, open structure represented below at fifty diameters, proving that thorough working of the steel had ceased while the metal was at a high temperature.
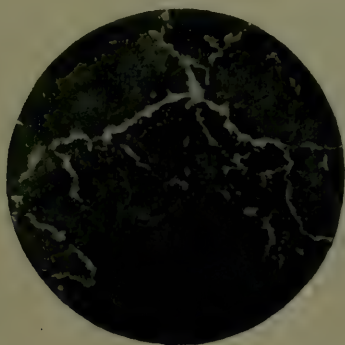


Centre of Fractured Locomotive Tire.—50 Diameters.

The above treatment resulted in material capable of relatively small resistance under sudden stress, whereas if worked to a proper finishing temperature, steel of the above composition would have been tough and highly resistant to such shocks.

The tire was made several years ago when much less attention than is now customary was given to the method of working the metal and temperature of finishing desirable to ensure the best results in service. ROBERT JOB.

Reading, February 2, 1904.

# IRON AND STEEL METALLURGICAL NOTES

**The Dixon Plug Ingot Mold.**[*] — The majority of ingot molds used today in the casting of crucible steel are made of gray iron, and are divided longitudinally into two equal parts which enables them to be placed together and held firmly by rings and wedges in order to be filled, and to be separated when extracting the ingot. Although the chemical laboratories of the several foundries making molds have made, in the last decade, several important changes in the composition of the molds with the hope of securing a more durable material, the drafting departments have made no advance, though the very high carbon of crucible steel is harder on the molds, the tendency being to cut into the molds at the point struck. As it is the bottom of the mold which the stream of liquid directly strikes, it is naturally that section which suffers most. As the hard steel cuts a portion of it away at each operation, the hole grows larger and deeper, causing a wasteful and unmanageable elongation of the ingot. When the bottom is deeply cut, the mold is ordinarily consigned to the scrap heap.
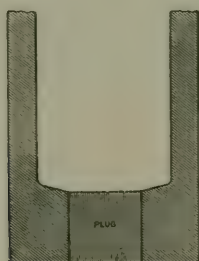


Ingot Mold Plug.

A recent patent granted to Thomas Dixon, of McKeesport, Pa., for an improved crucible mold, aims at a solution of the

problem. His invention does not alter the shape of the mold, the only difference being that instead of having each half to contain a portion of the bottom, a groove is left, thus permitting a plug to be inserted which, when the two halves are placed together, serves as the bottom. The grooves taper to a small degree from the outside to the inside of the mold, thus preventing the plug from dropping out of place when the mold is in its vertical position. The plug is either placed in position as the halves are being fastened together, or it is inserted from the top of the already fastened mold by means of a pair of tongs, care being taken that the plug enters the taper hole at the bottom and assumes its proper position. To insure this a red hot iron is inserted into the mold, illuminating the interior sufficiently for an examination. The plug, as well as the mold, is given a heavy coating of soot by being exposed to the smoke from a rosin fire, thus preventing the steel from sticking to the molds.

A test was recently made in which 210 heats were cast in one of these plug molds, the wear on the single plug being very moderate. The average for a solid-bottom crucible mold is about 32 heats, which means the discarding of the entire mold. Naturally the life of a mold depends greatly upon the grade of steel being cast as well as the skill of the teemer.

The following table shows the size molds in general use together with their weight and the weight of the plugs for each:

| Size of Mold | Weight of Mold | Weight of Plug |
|---|---|---|
| 3½ inches | 250 pounds | 5 pounds |
| 4 " | 293 " | 7 " |
| 5 " | 429 " | 12 " |
| 8 " | 777 " | 29 " |
| 9 " | 890 " | 48 " |
| 12 " | 1613 " | 75 " |

By experiments made at the Firth-Sterling Steel Co.'s plant, Demmler, Pa., it is found that the life of a plug mold is, on an average, five times as long as that of the old solid-bottom mold. As molds are somewhat expensive the invention will work a considerable economy, the original cost of the plug mold being only a trifle more expensive.

A company headed by T. H. Pollock, a contracting engineer of Monongahela, Pa., Karl G. Hoffman, Thos. Dixon

and Mr. Stentz of McKeesport, Pa., is now being formed for the manufacture of these molds.

**The Protection of Steel from Corrosion.**\* — Many experienced engineers have long claimed that iron or steel well buried in cement or concrete was absolutely safe against corrosion. In building the first Niagara suspension bridge Roebling relied entirely on his concrete to protect from rust his cables, and an examination made a few years ago, when the bridge was under repair, proved that his confidence had not been misplaced. No very exhaustive experiments on the matter have, however, hitherto been published, though, in view of the prominence which ferro-concrete is likely to take in future structural work, the point in question is now of more importance than ever. We have pleasure, therefore, in calling attention to some recent investigations of Prof. C. L. Norton, recently carried out at the Insurance Engineering Experiment Station, 31 Milk Street, Boston, Mass., U. S. A. In some preliminary work Professor Norton found that clean steel was thoroughly protected from rust when covered by Portland cement concrete to a depth of one inch. It was, however, suggested that in actual building operations the steel was never used in a clean condition, and it was of importance to determine whether the same security against rust was attained when the steel in question was already more or less oxidized on the surface. In view of the results of his latest experiment, Professor Norton has been able to answer this question in the affirmative. Specimens of rusty steel, on which the thickness of rust ranged from a mere surface coloration up to $\frac{1}{8}$-inch thick, were embedded in blocks of concrete of three inches square by eight inches long, and these blocks were then exposed to changing conditions of warmth and moisture, and to the action of carbonic acid, with traces of sulphurous acid and ammonia. When similarly treated, specimens of unprotected steel rapidly vanished into a streak of rust, but the samples protected by the concrete resisted perfectly. It has, however, to be borne in mind that if the steel is not properly covered by the concrete, corrosion may be expected; and care must be taken not

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\* "Engineering," January 22, 1904.

to mix the concrete too dry. If properly mixed, even cinder concrete proves a perfect protection to the embedded metal.

**Belgian Steel-Making.**\* — The John Cockerill Company is about to introduce some important changes into its steel works. The alterations are expected to extend over three years. The present installation comprises five Bessemer converters (three of ten tons and two of 12 tons each), and five Martin basic furnaces of 15 tons each. The present annual production of ingots is 185,000 tons; but by the addition of three Thomas converters and two Bessemer converters, the output will be carried to 300,000 tons per annum. The new converters will be of 15 tons each.

**American Institute of Mining Engineers.** — The following papers relating to iron and steel were read and discussed at the Atlantic City meeting (February 16 to 19) of the American Institute of Mining Engineers:

1. Note on the Further Discussion of the Physics of Cast Iron by William R. Webster, Philadelphia, Pa.
2. Note on the Physics of Cast Iron, by Richard G. G. Moldenke, New York City.
3. The Mobility of Molecules of Cast Iron, by Alexander E. Outerbridge, Jr., Philadelphia, Pa.
4. Chemical Specifications for Pig Iron, by Edgar S. Cook, Pottstown, Pa.
5. Specifications for Pig Iron and Iron Castings, by Robert Job, Reading, Pa.
6. Standardization of the Specifications for Cast Iron and Steel, by William R. Webster and Edgar Marburg, Philadelphia, Pa.
7. Specifications for Testing Cast Iron, by Henry Souther, Hartford, Conn.
8. Present Specifications for Cast Iron, by C. R. Baird, Philadelphia, Pa.
9. Specifications for Cast Iron and Finished Castings, by Dr. R. G. G. Moldenke, New York City.
10. Specifications for Car Wheels, by Dr. Charles B. Dudley, Altoona, Pa.
11. Specifications for Malleable Cast Iron, by Stanley G. Flagg, Jr. Philadelphia, Pa.
12. Specifications for Steel Rails, by Robert W. Hunt, Chicago, Ill.
13. Specifications for Iron Pipe, by Walter Wood, Philadelphia, Pa.
14. A Decade in Blast-Furnace Practice, by F. L. Grammar, Baltimore, Md.

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\* "Engineering," December 25, 1903.

15. Blast-Furnace and Cupola Metal Problems, by Thomas D. West Sharpsville, Pa.
16. Stock Distribution and its Relation to the Life of a Blast-Furnace Lining, by David Baker, Cape Breton, Canada.

These papers will be published in full in our next issue (April, 1904), which will be edited as a special number commemorative of this meeting of the American Institute of Mining Engineers. An extra large edition will be printed, but it is recommended that orders for extra copies be sent early so that the publishers may be better prepared to fill them.

**American Meeting of the Iron and Steel Institute.** — The Secretary of the Iron and Steel Institute has published a list of members who have intimated their present intention to take part in the autumn meeting to be held October 24-26, 1904, in New York City. The list includes 553 names exclusive of American members, but including candidates for election.

An influential committee has been formed in the United States for the reception of the Institute, Mr. Charles Kirchhoff being the President and Mr. Theodore Dwight (99 John Street, New York), the Honorary Secretary.

# REVIEW OF THE IRON AND STEEL MARKET

Since our last review, the main development has been in the direction of foreign trade; the domestic has shown a disappointingly small increase. The foreign business has been taken mainly by the United States Steel Corporation. The actual volume of foreign orders taken is not ascertainable, these operations being carefully concealed, but that it has been very large is shown by the fact that there has been a general resumption on the part of the blast-furnaces of the steel corporation, while there has been comparatively little resumption on the part of other furnaces.

At one time in December it is stated the steel corporation had only three furnaces in blast on regular steel-making pig, a few furnaces being operated on ferro-manganese, spiegeleisen and low-phosphorus pig, for the general market. There was a large stock of pig iron on hand, and during the period of idleness this stock was entirely consumed, so that while since the last few days of December the corporation has been starting one idle furnace after another until nearly all are in blast, a shortage of pig developed, which necessitated the closing of one steel works, the Schoenberger, in Pittsburg, when there were entered at the works orders for 20,000 tons of steel. The corporation now has practically all of its Pittsburg district furnaces in operation; the Chicago district furnaces are slower of resumption, as they do not operate for export trade.

As a general proposition, the foreign business of the steel corporation has been taken without profit, its advantage comes merely in helping to pay the fixed charges of some $5.00 per ton, which the corporation has before it earns anything on its first mortgage bonds.

The contingency referred to in our last report as a possibility in the southern iron situation has materialized. The effort to maintain southern iron on a $10 basis at Birmingham has been met by a declining instead of an advancing Northern market, and

it has become clear that this desired basis cannot be maintained. Already some southern furnaces are offering iron at very substantial concessions from the $10 price, and finding little sale. The ice having been broken, it now seems probable, rather than possible, as stated in our last report, that a new low point will be uncovered for southern iron, new as regards the low point made last November, which was between $8.75 and $9.00.

The annual pig-iron statistics showed that 1903 slightly surpassed 1902, and therefore previous years, in production. The production of the latter half of 1903 was far below the average of the first half, and there is every reason to believe that the calendar year 1904 will fall below the record of 1903.

One of the greatest drags on the finished steel situation is the continued refusal of the rail association to reduce the price of standard rails, which remains at the $28 figure established early in 1901. The railroads have a right to expect a lower price, now that nearly every finished steel product has been reduced since the high level of 1901 and 1902. Light rails, made either from old rails by the rerolling process, or from new stock, are selling at several dollars a ton below the price of standard sections, when normally they sell higher, while the railroads are receiving nearly $10 per ton less for their old rails than they did when they were large purchasers of rails at $28. As the great bulk of rails purchased now is for replacement purposes, this increased spread greatly enhances the actual cost of replacement. The situation has been further strained by a number of sales of rails for export at prices netting the mills from $7 to $10 per ton less than the domestic price.

*Pig Iron.* — Prices are about as follows: At Birmingham: No. 2 foundry, $9.50, with 50 cents between grade numbers, but it would appear the market is being shaded by offerings of iron technically but hardly practically " off " in analysis, at special prices. At Pittsburg: Bessemer, $13.60 to $13.85; foundry No. 2, $13.15 to $13.60; forge, $12.75 to $13. Mahoning or Shenango valley furnace: Bessemer, $12.75 to $13; foundry, $12.50 to $12.75; forge, $12. At Chicago: local foundry, $13.75 to $14. At Philadelphia: No. 2X foundry, $14.25 to $14.50; No. 2 plain, $13.75 to $14.

*Billets.* — The prices of the billet association are being shaded in the West by the quotations of the Ashland interest, which has

been selling at $21, f.o.b Ashland, Ky.; in the Pittsburg district there are rumors of shading. The association prices are: 4 × 4 and larger Bessemer or open-hearth billets, carbon up to 0.25 per cent, delivered Pittsburg, Wheeling, valleys, Johnstown, Ashland, Lorain, $23; Philadelphia and Baltimore, $24.25; Chicago, $24; Cleveland, $23.50; New York, $24.75; advances: carbons, 0.26 to 0.60 per cent, $1; 0.61 to 1.00 per cent, $2; billets, 3⅞-inch and smaller, and sheet bars, long lengths, $1; cutting sheet bars to specifications, 50 cents. Wire rods are $30.

*Merchant Bars.* — Steel, 1.30 cents, half extras, carload or larger lots, f.o.b. Pittsburg, plus full rail freight to destination; common iron, 1.30 cents, half extras, carload or larger lots, f.o.b. Ohio mills, a few sales being made at the former price of 1.25 cents.

*Plates.* — Official prices: tank quality, one-quarter-inch and heavier, 100 inches wide and narrower, 1.60c, carload or larger lots, f.o.b. Pittsburg, plus full rail freight to destination; advances, three-sixteenth-inch, 0.01c; wider than 100 inches, 0.05c; flange and boiler quality, 0.10c; ordinary firebox, A. B. M. A. specifications, 0.20c. These plate association prices are being shaded to some extent on skelp widths, also on thin plates.

*Shapes.* — Tees, angles, three to six-inch, beams and channels, three to 15-inch, 1.60c; tees, 1.65c; beams and channels, 18 to 24-inch, 1.70c; all carload and larger lots, f.o.b. Pittsburg, plus full rail freight to destination.

*Sheets.* — All the independent sheet mills but two have agreed upon a list which conforms to that of the leading interest, putting No. 28 gauge at 2.30c for black and 3.30c for galvanized.

# STATISTICS

**Another Record Year in American Pig Iron Production.**
— With his usual admirable promptness, General Manager
James M. Swank of the American Iron and Steel Association
has collected and made public the statistics of pig iron pro-
duction in the United States in the calendar year 1903. The
statistics of production of other countries will in general not
be available for several months yet.

The year 1903 is the seventh successive year in which the
United States has broken all previous records in the produc-
tion of pig iron, 1896 having been the most recent year which
did not break a record. Since the production passed the
million-ton mark, in 1864, there have been four periods ex-
ceeding a couple of years, in which all records have been
broken, these having been the four years 1866-9, the four years
1879-82, the five years 1886-90, and the seven years 1897-1903.
As the industry has expanded, the periods of continuous an-
nual increase have lengthened. The increase has been uni-
form, not in tonnage, but in percentage over previous years.
If the production were plotted, with ordinates based on
tonnage and abscissæ on time, the smoothing curve would
trend continually upward, and the curve would show approxi-
mately that the production has doubled every ten years, for
almost four decades. Clear back to 1863, however, the curve
cannot properly be traced. The production in 1863 was not
as much as one-sixteenth that of 1903, or 1,125,000 tons; it was
846,000 tons, but this only accentuates the truth of the general
principle, since at that time the product of the Catalan forge
was of commercial importance, and the production of pig iron
was then not, as it has been for about three decades, a true
measure of the production of the malleable products known
commercially as puddled iron, crucible, Bessemer and open-
hearth steel, etc.

The following table shows in detail the production of pig

iron by states, as well as by districts in Pennsylvania and Ohio, the totals for these two states being included in parentheses, as they do not themselves contribute to the total:

### Total Production of Pig Iron in the United States in 1903, Tons of 2,240 Pounds

| States and districts | First half | Second half | Whole year |
|---|---|---|---|
| Massachusetts | 1,419 | 1,846 | 3,265 |
| Connecticut | 7,142 | 7,359 | 14,501 |
| New York | 270,443 | 282,474 | 552,917 |
| New Jersey | 106,387 | 105,280 | 211,667 |
| Pennsylvania | (4,498,038) | (3,713,462) | (8,211,500) |
|   Lehigh Valley | 370,477 | 278,344 | 648,821 |
|   Schuylkill Valley | 311,299 | 239,261 | 550,560 |
|   Lower Susquehanna Valley | 271,305 | 226,301 | 497,606 |
|   Juniata Valley | 124,867 | 108,832 | 233,699 |
|   Allegheny County | 2,255,389 | 1,956,180 | 4,211,569 |
|   Shenango Valley | 720,800 | 417,361 | 1,138,161 |
|   Miscellaneous bituminous | 442,607 | 484,407 | 927,014 |
|   Charcoal | 1,294 | 2,776 | 4,070 |
| Maryland | 166,801 | 157,769 | 324,570 |
| Virginia | 322,529 | 221,505 | 544,034 |
| North Carolina and Georgia | 34,001 | 41,601 | 75,602 |
| Alabama | 777,870 | 783,528 | 1,561,398 |
| Texas | 5,023 | 6,630 | 11,653 |
| West Virginia | 106,970 | 92,043 | 199,013 |
| Kentucky | 53,034 | 49,407 | 102,441 |
| Tennessee | 227,259 | 191,109 | 418,368 |
| Ohio | (1,860,334) | (1,427,100) | (3,287,434) |
|   Mahoning Valley | 714,792 | 549,167 | 1,263,959 |
|   Hocking Valley | 21,800 | 5,100 | 26,900 |
|   Lake counties | 465,691 | 363,213 | 828,904 |
|   Miscellaneous bituminous | 472,400 | 358,052 | 830,452 |
|   Hanging Rock bituminous | 182,345 | 145,334 | 327,679 |
|   Hanging Rock charcoal | 3,306 | 6,234 | 9,540 |
| Illinois | 838,655 | 853,720 | 1,692,375 |
| Michigan | 111,953 | 132,756 | 244,709 |
| Wisconsin and Minnesota | 157,241 | 126,275 | 283,516 |
| Missouri, Colorado, Oregon and Washington | 162,268 | 108,021 | 270,289 |
| Totals | 9,707,367 | 8,301,885 | 18,009,252 |

The following table shows the production in 1903 according to fuel:

| | |
|---|---|
| Bituminous coal and coke | 15,592,221 |
| Anthracite and coke | 1,911,347 |
| Charcoal and coke | 927 |
| Charcoal | 504,757 |
| Total | 18,009,252 |

The following table compares the production according to grade in 1902 and 1903:

|  | 1902 | 1903 | Change |
|---|---|---|---|
| Bessemer and low phosphorus . . . . | 10,393,168 | 9,989,908 | —403,260 |
| Basic . . . . . . . . . . . . . . | 2,038,590 | 2,040,726 | +12,136 |
| Spiegeleisen and ferro-manganese . . . | 212,981 | 192,661 | —20,320 |
| Forge, foundry, etc. . . . . . . . | 5,176,568 | 5,785,957 | +609,389 |
| Totals . . . . . . . | 17,821,307 | 18,009,252 | +187,945 |

The item " Bessemer and low phosphorus " refers only to pig iron for use in the Bessemer process and to a grade of especially low phosphorus and low sulphur used principally in the manufacture of acid open-hearth steel castings. The term basic simply includes pig iron intended for the basic open-hearth process, ordinarily running high in phosphorus, although there is probably some iron included of an analysis approaching standard Bessemer, but actually used on the basic open-hearth. The last item is obtained by difference and therefore includes, besides forge and foundry, a comparatively small quantity of malleable Bessemer, white, mottled and miscellaneous grades, and direct castings.

There was a remarkable slump in production in 1903, the production of the second half being 1,405,482 tons less than that of the first half. The production in the second half of 1902 and the first half of 1903 exceeded that of the calendar year 1903 by 710,848 tons, thus establishing a twelve-month record quite different from that of the calendar year. This is not the first time that such a variation has occurred, as appears from the following presentation :

*Total Pig Iron Production of the United States, by Six and Twelve-Month Periods, Tons of 2,240 Pounds*

| Year | 6 months ended June 30 | 6 months ended Dec. 31 | 12 months ended Dec. 31 | 12 months ended June 30 |
|---|---|---|---|---|
| 1897 . . . | 4,403,476 | 5,249,204 | 9,652,680 | 8,050,367 |
| 1898 . . . | 5,869,703 | 5,904,231 | 11,773,934 | 11,118,907 |
| 1899 . . . | 6,289,167 | 7,331,536 | 13,620.703 | 12,193,398 |
| 1900 . . . | 7,642,569 | 6,146,673 | 13,789,242 | 14,974,105 |
| 1901 . . . | 7,674,613 | 8,203,741 | 15,878,354 | 13,821,286 |
| 1902 . . . | 8,808,574 | 9,012,733 | 17,821,307 | 17,012,315 |
| 1903 . . . | 9,707,367 | 8,301,885 | 18,009,252 | 18,720,100 |

**Connellsville Coke Production.** — According to the statistics gathered by the " Connellsville Courier," the Connellsville

coke production, in net tons of 2,000 pounds, has been as follows in 1903, compared with 1902:

| | |
|---|---:|
| Connellsville region proper | 10,870,448 |
| Lower Connellsville | 2,474,782 |
| Total, 1903 | 13,345,230 |
| Total, 1902 | 14,138,740 |
| Decrease | 793,510 |

The decrease was due entirely to the slump in the last two months, during which shipments were less than half the average of the preceding ten months. The " Courier " estimates the average value of the 1903 product at $3.00 per ton, against $2.37 in 1902, which would place a total value on the 1903 product of a trifle over $40,000,000, or $6,500,000 in excess of that in 1902.

**British Blast-Furnaces.** * — The completion of the returns of the blast-furnaces for the United Kingdom enable a contrast to be made of the figures with those of past periods. We have the officially vouched-for facts for past years, and the statements that are approximately correct for the last year. The number of blast-furnaces in the kingdom has for some time been changing. In 1899 there were about 411 in operation — the highest number for a decade — but the number has decreased yearly, and at the end of the past year it was computed that about 340 were in blast. But whilst the number has been decreasing, the furnaces have been improved in size and in extent of production, so that the decrease in the amount produced is much less in proportion. Putting the figures of the pig iron actually made in early years against those that are estimated for the past year we have a contrast which may be put as below:

| | |
|---|---|
| 1892 | 6,709,000 tons |
| 1899 | 9,421,000 " |
| 1902 | 8,679,000 " |
| 1903 (estimated) | 8,500,000 " |

It would thus seem that the production had reached its maximum in 1899 after a few years of comparative dulness in the extent of the output. It decreased after that year, the twelve months of 1901 having been below any year since 1895.

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* " Iron and Steel Trades Journal," January 16, 1904.

In 1902 there was a sharp advance; and whilst the last two or three months of the past year have witnessed a falling off, yet the production for 1903 will not have been so much below its predecessor as might have been expected from the figures given of the number of the furnaces at work. And it is also to be remembered that not only has the production of pig iron of the past year been well taken up, but there has been a not inconsiderable reduction of the stocks that had accumulated in the warrant stores — that reduction having been seen in both the Scotch and Cleveland stores.

**Blast-Furnaces in France.** — According to the " Écho des Mines et de la Métallurgie " for January 18, 1904, out of a total number of 158 French blast-furnaces 109 were in blast January 1, with a total capacity of 9,238 tons per 24 hours.

# RECENT PUBLICATIONS

*Modern Iron Foundry Practice. Part I.,* by Geogre R. Bale; 387 7 × 4½ pages. 208 illustrations. The Technical Publishing Company, Ltd. London. 1902. Price, $2.50. — The author states that this book was prepared to meet the existing want of a Manual of Modern Iron Foundry Practice. This first part contains, besides an introduction, fourteen chapters, bearing the following titles: Moulding Sands, the Cupola and its Charge, Reverberatory Furnaces, the Blast and its Production, Ladles, Cranes and Hoists, the Preparation of Moulding Sands, Moulding, Green-sand Moulding, Core Ovens, and Drying Stoves, Dry-sand Moulding, Loam Moulding, Chilled Castings, Malleable Castings.

*Points for Buyers and Users of Tools,* by George W. Alling; 224 5½ × 8 in. pages. 62 illustrations. David Williams Co. New York. 1903. Price, $2.00. — The author describes his book as being designed for those who have not had the benefit of a technical education so as to enable them to extract from the numerous books that have been written on this subject the information which he has attempted to give in plainer language. Students as well as producers and workers of iron and steel should find in this excellent little book much that is of interest and value. The author's demonstrations of the necessity of heating steel to the proper temperature, both in annealing and hardening, are of especial interest. Many excellent illustrations are embodied in the book, which contains also a number of useful reference tables.

*Resistance of Materials and Stability of Structures* (Résistance des Matériaux et Stabilité des Constructions Civiles), by Abel de Villiers de l'Isle-Adam; 332 9 × 5½ pages. 61 illustrations. Paper cover. Vve. Ch. Dunod. Paris. 1903. Price, 10 francs. — The aim of the author has been to present concisely and clearly those principles of the resistance of materials which are

needed for the erection of structures, and to avoid long, mathematical considerations. His book should be a useful and ready guide for constructing engineers.

*Ore Dressing* (in two volumes), by Robert H. Richards, Professor of Mining Engineering and Metallurgy at the Massachusetts Institute of Technology; 1,236 6 × 9 inch pages. Nearly 600 illustrations. The Engineering and Mining Journal. New York. 1903. Price, $10.00. — The distinguished author of this book has for many years occupied the foremost place among experts in the art of ore dressing. When it became known, some ten years ago, that he had undertaken the writing of a book in which he was to embody a portion at least of his mint of information and of the results of his original researches, the news was gladly received by those interested in ore dressing, and ever since, the publication of this much longed-for book has been awaited with keen anticipation. The waiting has been long, but abundant compensation for it is found in the monumental work the author has produced. To review it, properly, however, would require an amount of space which is not available. Professor Richards's book takes at once a foremost place among classical works in applied science. That it will retain this leading position for many years can hardly be doubted. Indeed it is difficult to conceive how it could be superseded in this generation or the next!

*Mineral Industries and Allied Sciences;* 302 4 × 6½ pages. Paper cover. Patent office. London. 1903. Price, six pence. — This little book consists of a subject list of works on the mineral industries and allied sciences in the library of the patent office. It comprises 2,559 works (243 serials and 2,316 books) representing some 5,662 volumes. The classification includes (a) a general alphabet of subject headings, and (b) a key, or a summary of these headings showing class order.

*The Analytical Chemistry of Uranium,* by Harry Brearly; 45 4½ × 8½ pages. Semi-flexible cover. Longmans, Green & Co. London. 1903. Price, two shillings. — The author describes the methods of determining Uranium, its separation from the metals with which it is usually associated and the analysis of uranium ores. He is to be congratulated for his conduct of such

an excellent analytical research. As he rightly says, if each element were dealt with in such a manner, the accumulated result would save much vexation and laborious search.

*A Manual on the Care and Handling of Electric Plants,* by Norman H. Schneider; 104 4 × 6¼ pages. 66 illustrations. Flexible cover. Spon & Chamberlain. 1903. Price, $1.00. — This little book is written for the practical engineer and adapted to the United States Military Service. It includes dynamos, motors, wiring, storage batteries, testing and incandescent lamps, as well as a chapter on the oil engine.

# PATENTS

## RELATING TO THE METALLURGY OF IRON AND STEEL

### UNITED STATES

747,965. Gas-Producer. — Jerome R. George, Worcester, Mass., assignor to Morgan Construction Company, Worcester, Mass. In the feeding mechanism of a gas-producer, the combination with a stationary coal-reservoir having an opening in its bottom, of a stationary plate held concentrically above said opening, but of less diameter than the opening, whereby an annular space is left around said plate for the passage of coal, a rotating coal-distributor provided with a horizontal bottom extending beneath said plate, bent, fixed ribs on the under side of said plate and oppositely-bent, rotating ribs carried by said coal-distributor, whereby the coal is moved from said horizontal bottom.*

748,061. Process of Casting. — Herbert H. Franklin, Syracuse, N. Y. A process of casting with a sectional mould, the same consisting in supplying to the mould the material to be cast and in removing the air from the mould through a narrow space formed by separating contiguous surfaces of sections of the mould during the entrance of the material to be cast, said space being too narrow to permit the escape of the material to be cast.*

748,107. Apparatus for Detecting the Temperature of Metals. — Albert Sauveur, Cambridge, and Jasper Whiting, Lexington, Mass. The combination, with mechanism for working hot metal, of a magnet, and means to indicate the response or non-response of the metal to the magnetic influence.*

748,222. Ingot-Tongs. — Edwin S. Sites, Apollo, Pa. Automatic tongs or ingot-dogs comprising members and pivotally secured together, whereby the lower ends thereof will form a pair of co-operating jaws, each of said members having pivotally connected to its upper end a link-section, the ends of said link-section being pivotally secured together; a clevis-like member pivoted to said link-sections and designed to receive a rope, hook or the like of the lifting-crane, said members also having interlocking arms, a hook-like member mounted in compensating slots provided in the members, and an arm provided with a hook at its lower end adapted to co-operate with the members.*

748,842. Case-Hardening Compound. — Jos. Cadotte, Suncock, N. H. A case-hardening dry compound composed of 40 per cent of white calcined plaster, 40 per cent of prussiate of potash and 20 per cent of lampblack.*

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* " Engineering and Mining Journal."

749,049. MACHINE FOR HANDLING INGOTS OR LIKE PIECES UNDER THE HAMMER. — George P. Foy, Homestead, Pa.; Lizzie Foy, administratrix of said George P. Foy, deceased, assignor of one-half to Arthur Neill, Pittsburg, Pa. In a machine for handling an ingot or the like, the combination, with a car, of a bed rotatably mounted thereon, a base-plate adapted to be moved across the bed, standards carried by said base-plate, a vertically-movable frame mounted so as to slide in the standards, means carried by the frame for holding the ingot or like piece of material, and means for controlling the vertical movement of the frame.*

749,115. MANUFACTURE OF STEEL AND INGOT-IRON. — Benjamin Talbot, Leeds, England, and Paul Gredt, Luxemburg, Germany, assignors to the Continuous Metal Refining Company, Philadelphia, Pa. The process of manufacturing steel and ingot-iron consisting in first purifying a charge of metal by blowing it in a Bessemer converter or similar vessel then running off a portion of the charge, then adding to the remainder a further charge of impure metal and blowing the combined charge.*

749,258. IRON-FOUNDING. —-Haggert S. Cochran, Kansas City, Mo., administrator of Adam Cochran, deceased. A process of purifying and refining iron, consisting in first charging the cupola with fuel and metal and raising the heat of the contents thereof to a high temperature by an air-blast; second, injecting steam in an angular downward direction through the mass of molten iron and incandescent fuel, said steam entering the cupola at about 10 in. below the melting-point of iron.*

749,403. MOVABLE SWINGING-BODY FURNACE FOR MELTING STEEL, ETC. — Louis Rousseau, Paris, France. A furnace for melting metals comprising a fire-chamber, provided below with a bent grate mounted upon an axis carried by the lower part of the refractory furnace-lining, a partition in the fire-chamber supported upon the refractory lining and provided with an opening; a plumbago crucible provided with a neck and supplied beneath with legs supported upon the lower wall of the refractory lining, a flue traversed by the legs and arranged between the crucible and the lower and side refractory lining.*

749,502. APPARATUS FOR HEATING AIR FOR SUPPLYING BLAST-FURNACES. — George Teichgraeber, Marchienne au Pont, Belgium. An apparatus for heating the air for supplying blast-furnaces, the combination of a plurality of regenerator-flues, a dome placed above said flues, a gas-passage, a plurality of gas-inlet passages leading from said gas-passage into said dome, an air-passage, a plurality of air-inlet passages leading from said air-passage into said dome, said gas and air-inlet passages being located in the same plane, an inlet for cold air beneath said regenerator-flues and an outlet for said air after it has been heated by said flues.*

749,679. ROLLS FOR USE IN THE PRODUCTION OF SHEET-METAL STRIPS. — Godfrey B. Johnson, London, England. A pair of rolls for shaping the cross-section of sheet-metal strips, consisting in the combination with a pair of shafts rotated at the same angular velocity, of independent annular sections carried thereby and constituting the operative surfaces of the rolls.*

* " Engineering and Mining Journal."

749,490. Ingot and Process of Forming Same. — Horace W. Lash, Minneapolis, Minn. An improvement in the art of forming metal ingots that consists in preparing a mass of molten steel, then inserting a piece of cold metal into said mass, thereby causing the molten steel to form or settle upon the exterior of said piece and thus form an ingot and then withdrawing such ingot from the molten mass prior to the general solidification of said mass.*

## GREAT BRITAIN

17,434 of 1903. Reduction of Iron and Other Metals from Their Ores. — B. J. B. Mills (a communication from C. S. Bradley, of New York, U. S. A.). The object of the invention is to effect such reduction by the interaction of the ores without the intervention of a reducing-blast, such as is involved in the usual blast-furnace operations. The invention consists in heating the oxide and sulphide of iron or similar refractory oxide and sulphide ores, in an electric furnace, the proportion of the oxide and sulphide being such that a portion of the sulphur will be expelled and the remainder taken up by the oxygen of the ore, and nearly the whole of the iron or metal will be freed in the metallic state. The process is applicable to other metals of the iron group.†

264. Rolling or Welding Tubes. — G. A. Lambert and H. A. Cardozo, Paris, France. [2 Figs.] January 5, 1903. The improved machine sub-



stantially comprises two series of grooved cylindrical rollers mounted loosely on axles at each side of the work to be rolled, the said rollers being rotated about axes eccentric with regard to the axis of the work, the latter being mounted on a mandrel to which continuous helical movement is imparted. The helical movement produces a torsion of the fibre of the work at the same time as the latter is compressed by the rollers, so that greater strength is imparted to the tubes, and their separation from the mandrel is facilitated. The tubular body to be rolled is heated and then placed on the mandrel *i*, which is driven by gearing so as to receive a helical advancing movement. The work placed on the mandrel is engaged between two of the grooved
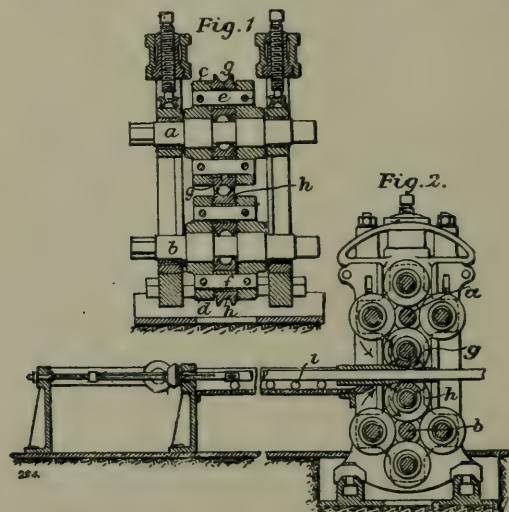
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* "Engineering and Mining Journal."
† " Electro-Chemist and Metallurgist."

rollers *g* and *h*. These rollers *g* and *h* are loosely mounted on axles *e* and *f* carried by plates *c* and *d*. The plates *c* and *d* are themselves carried by axles *a* and *b*, which are simultaneously rotated in opposite directions and at equal speeds. Since a high speed of rotation can be imparted to the rollers, a reduction of section with one heating of the work can be obtained by the rapid repeated actions of the rollers, more rapidly than is possible by means of apparatus hitherto known. This is of considerable advantage with metals which have to be treated in a heated condition, and more particularly in the case of metals which can only be heated within narrow limits of temperature. (Accepted November 11, 1903.)*

704 of 1903. CEMENTATION OF IRON. — J. Lecarme, Paris, France. Cementing the surface of iron by covering with a plastic mixture of charcoal and a solution of a cyanide which gives off gases rapidly when heated and so accelerates the cementation process.†

16,350 of 1903. STAMP-MILL TAPPET. — Sandycroft Foundry Company, Ltd., Chester. Improved tappets for the shaft of stamp-mills.†

21,642 of 1903. DRYING BLAST. — J. Gayley, New York, U. S. A. Apparatus for extracting moisture from air supplied to blast-furnaces and converters.†

25,954 of 1902. MAKING ALLOYS. — Schukert & Company, Nuremburg, Germany. Obtaining alloys, such as ferrochrome or ferromanganese, used in steel making, almost free from carbon, by passing the metal through a highly-heated oxide of the same, and so removing the carbon.†

2,612 of 1903. STEEL MAKING. — S. Parfitt, Cardiff. Adding a small percentage of aluminium instead of carbon in the manufacture of steel, so as to make a steel capable of withstanding the action of salt water.†

18,159 of 1903. FLUX FOR WELDING. — F. Todd, Newcastle-on-Tyne. Improved flux for welding steel consisting of a mixture of boracic acid, borax, iron filings, carbonate of potash, nitrate of potash, ammonium chloride and silver sand.†

## GERMANY

Kl. 49f. Nr. 142,600, December 22, 1901. DEVICE FOR THE HARDENING OF STEEL ON THE SURFACE OR ONLY AT SINGLE POINTS OF THE SURFACE. — Cleland Davis in Washington. A lack of economy of the heat used in tempering pieces of metal is avoided by not heating the entire piece of metal, but only the part to be hardened, namely, the head in rails, and the exposed parts in armor plate. Accordingly it is heated by means of an electric current, in such a way that only one of the two electrodes is joined to the piece of metal, the other being brought behind into incomplete contact. By closing the current, heat is developed only on the parts traversed by the current, while the remaining portions of the piece of metal receive only a slight heating, which does no harm as regards the process of hardening. Heating follows in accordance with the closing of the current. After heating, hardening is brought about by a quick cooling.‡

Kl. 7a. Nr. 143,532, September 16, 1900. DEVICE FOR THE ROLLING OF

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* "Engineering," London.
† "Engineering and Mining Journal."
‡ "Stahl und Eisen."

TUBES. — Wilhelm Junge in M. Hesterburg b. Rüggeberg. To the piece
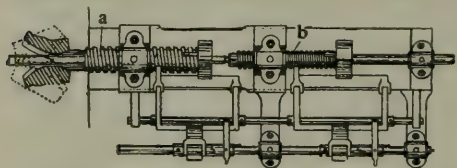


of metal is imparted during most of the operation of rolling, a greater axial speed than to the pointed bar, and not until the end of the rolling does it have a speed equal to the pointed bar. This equalizes the cooling and increases the capacity for resistance of the piece of metal through the diminished pushing forward through the rollers. For the operation of this device, a feeding contrivance is used, having a hollow and a solid screw provided with a disk plate and lifting bolt. The hollow screw *a,* with a greater pitch of the screw, gives to the piece of metal, during the greater part of the process of rolling, a greater axial forward impulse than the pointed bar and the solid screw have. The solid screw *b* toward the end of the rolling process, and after the setting free of the hollow screw, receives the impulse of the piece of metal and of the pointed bar, only with a slower speed.*

Kl. 12e. Nr. 143,857, May 24, 1902. APPARATUS FOR CLEANING DUST, ETC., FROM GAS. — Edward Lloyd Pease in Hurworth Moor (England). There is a cleaner by which the gases or the like to be cleaned are drawn from the outer to the inner part of a rotating cylinder, which is provided with a mantel-opening. Thus they are drawn against the centrifugal force, and are cleaned by this, the dust being drawn outward. In order to increase the working power of this machine its working surface is increased by making the rotating parts of a great number of thin disks, which are arranged close together on a common rotating axis. The air, etc., laden with dust and the like is drawn though the spaces between the disks against the centrifugal force and into the inner drum.*

Kl. 18a. Nr. 144,530, August 7, 1901. CHARGING DEVICE FOR BLAST-FURNACES. — P. Eyermann in Brooklyn. The charging takes place by means of a central tube *a,* leading to the furnace, and capable of being closed by the bell *b.* In the tube *a* is a screw *c,* which makes an equal distribution of the material in the tube *a,* and at the same time causes the gases to condense in the upper part. From this revolving tube *a,* open below, the material is carried through a side opening into the furnace.*
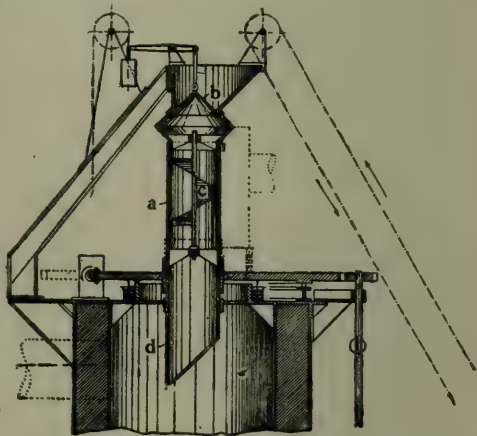


Kl. 18a. Nr. 143,506, March 8, 1902. DEVICE FOR THE MANUFACTURE OF FERRO-SILICON WITH SIMULTANEOUS PRODUCTION OF ALKALIS OR EARTH

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* "Stahl und Eisen."

ALKALIS. — Gustav Gin in Paris. Alkali or earth alkali-silicate is melted in an electric furnace with carbon and iron oxide, or metallic iron in a fixed quantity. There results silicon, iron, alkali or earth-alkali-oxide, which latter occurs either as slag or as sublimate. The process is according to the following formula:

$$BaSiO_3 + Fe_2O_2 \times 5C = Fe_2Si \times BaO + 5CO, \text{ or}$$
$$BaSiO_3 + 2Fe \times 2C = Fe_2Si + BaO + 2CO.*$$
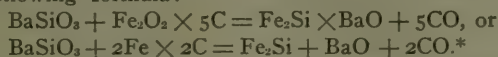
Kl. 7a. Nr. 143,340, January 11, 1902. TUBE ROLLING MILL. — William Pilkington in Erdington (Warwick, England). In order to hold the point and the pointed rod $p$, and for keeping them firm against the push and pull of the rollers in all directions, as well as to avoid a bending or shaking of the tube, a grinding table is so arranged that this is easily moved by a piston and rod $e$. The table is carried in the bar $l$ by means of sliding pieces $k$, which join the rear support with the case of the rollers. Crosswise to the direction of motion of the table, and upon it, are placed a number of transverse pieces $n$ and $o$, which lie against the narrow bracket plates $m$ at the near and forward end of the table. These transverse pieces are pierced with holes which conform to the number and position of the caliber of the rollers. The openings in the transverse $o$ are so great that they let the pointed bar through easily; while the holes which pierce the transverse $n$ are so great that they let the tube go completely through. On the bar $p$ slides the transverse $q$, which is intended to push the tube.*
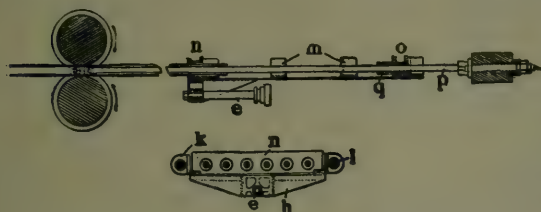
Kl. 18a. Nr. 144,043, September 19, 1902. LINING FOR STONE HOT BLAST-STOVES AND OTHER HEATING CHAMBERS. — Robert George Teichgraber in Malaga. The lining consists of different stones, alternating in layers. One layer of stone is made of stones $b$ in the form of plates, which form a continuous whole, provided with openings for the canals $a$. The other layer of stones is made up of stones in the form of columns, which form the same canals $a$, but are not continuous. Moreover the perpendicular joints of these are of such a width that the gas can pass from one canal to another. Moreover the heating surface is essentially increased by the method of building.*
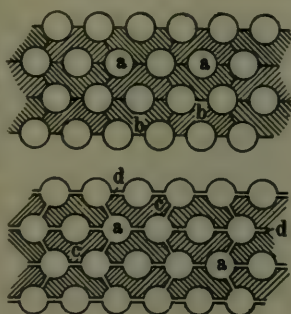
Kl. 18a. Nr. 141,567, September 17, 1901. DEVICE FOR DIRECT IRON AND STEEL PRODUCTION. — Carl Otto in Dresden. The production of iron from its ores takes place in a reducing vessel, heated from without, and

* "Stahl und Eisen."

closed to fire gases. Compare Patent Nr. 86,875, "Stahl u. Eisen," 1896, S. 683. In order to preserve the ore from the ashy constituents of the reducing material (carbon), only a small portion of the carbon is mixed with the ore, the greater part is brought above or near the ore in a special receiver. The reduction of the ore is accomplished by the small quantity of the carbon mixed with it, and the resulting carbonic acid is reduced to carbon oxide by means of the dissolved carbon, which then reduces the ore further.*

Kl. 40a. Nr. 142,435, August 17, 1902. ROASTING FURNACE WITH REVOLVING ANNULAR HEARTH. — Roman von Lelewsky in Birkengang b.
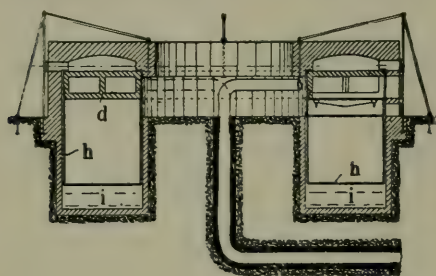
Stolberg (Rhld.). In contrast to the roasting furnace with revolving ring-shaped hearth, which runs on wheels and rails, the new hearth *d* is placed upon a ring-shaped receiver full of water. The way by toothed wheels or a hearth is worked in the usual rope. Since there is little friction the power required is much less than in roasting furnaces hitherto.*

Kl. 7a. Nr. 141,501, August 30, 1902. HOUSING FRAME FOR SIMULTANEOUS FINISHING OF TWO OR MORE WIRES. — Röchlingsche Eisen und Stahl werke G. m. b. H., in Völklingen a. Saar. Each wire passes through its own pair of finishing rollers, which can be adjusted separately. All the finishing rollers are placed in a frame so that one man can work them. By this arrangement a sufficiently uniform thickness is given to the wires rolled out together.*
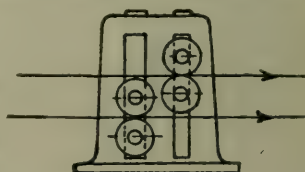
Kl. Nr. 145,184, January 1, 1902. PNEUMATIC ROLLING OR WORK TABLE. — Theodore J. Vollkommer in Pittsburg (V. St. A.). In the pneumatic rolling and work table in which the pieces of metal to be transported are lifted and carried along by means of compressed air issuing from the holes of the table board, the pieces of metal frequently receive a movement not intended yet often very swift, especially upon the deeper part of the table. In this device the motion is regulated thus: An endless chain *b* runs in a groove close to the table. In the groove are the holes *e*, and over them the springs *c*. These are pushed against a rail *d*, by means of the compressed air going through, which again lifts the transporting chain *b* so much that it takes along the piece of metal *w* by friction.*
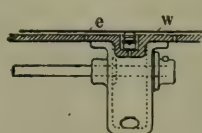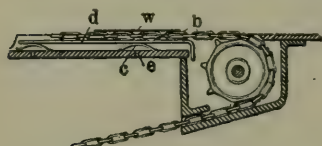
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* " Stahl und Eisen."
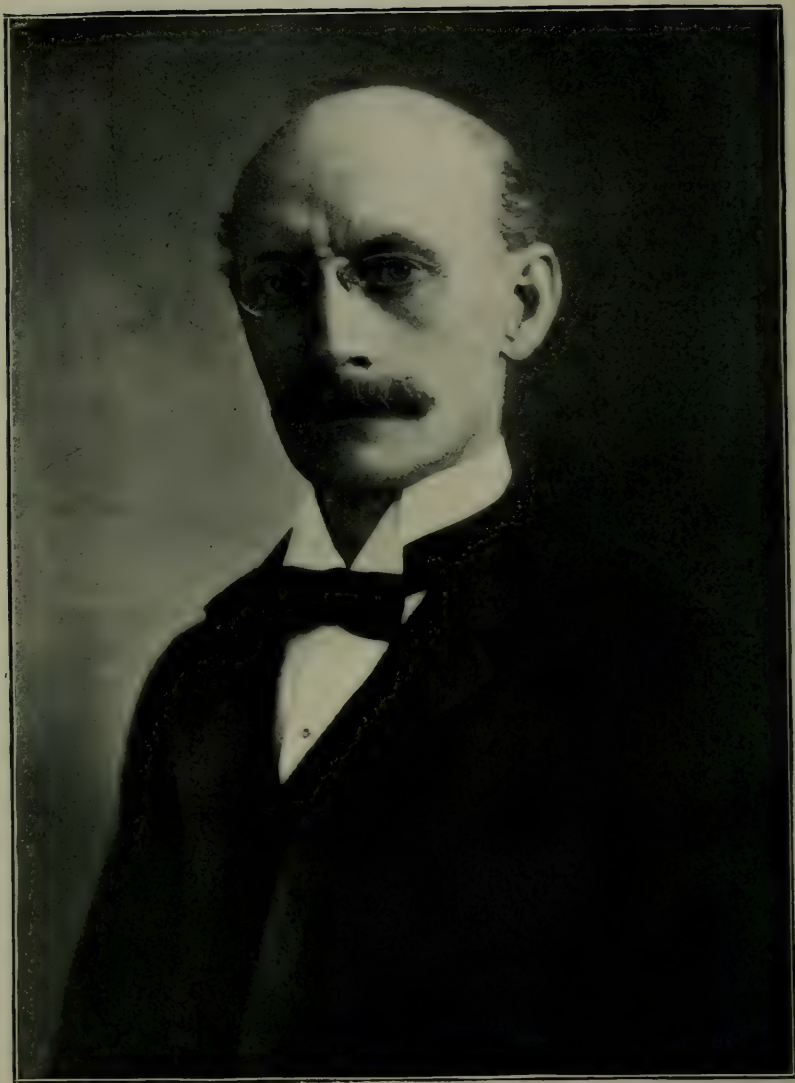
JAMES GAYLEY

FIRST VICE-PRESIDENT OF THE UNITED STATES STEEL CORPORATION AND
PRESIDENT ELECT OF THE AMERICAN INSTITUTE OF MINING ENGINEERS

## AMERICAN INSTITUTE OF MINING ENGINEERS

### Atlantic City Meeting, February, 1904

THE present issue of the *Iron and Steel Metallurgist* has been edited as a special number commemorative of the eighty-sixth meeting of the American Institute of Mining Engineers (being the thirty-fourth annual meeting) which was held at Atlantic City, February 16 to 19, 1904.

The Editor desires to express his appreciation to Mr. R. W. Raymond, Secretary of the Institute, and to Dr. Joseph Struthers, Asst. Editor, for their valuable assistance and good will.

With three exceptions all the papers dealing with iron and steel which were presented at the meeting will be found reproduced in full together with whatever discussion had been received by the Secretary. The papers by Messrs. Baird, Flagg and Dudley were not received in time to appear in the present issue.

The following is for the most part extracted from the official account of the proceedings of the meeting:

The city of Baltimore, Md., was originally selected for the place of the annual meeting; but the disastrous conflagration which began there on February 7, and devastated a large part of the business section of the city, necessitated the immediate selection of another place of meeting. The choice of Atlantic City, N. J., at so late a date, left no time for the arrangement of

excursions or entertainments, such as have always formed an attractive feature of the meetings of the Institute. The hotel-head-quarters' bureau of information, and hall for all the sessions, were in the Hotel Rudolf.

The opening session was held on Tuesday evening, February 16. President Albert R. Ledoux called the meeting to order and after welcoming the members of the Institute and their guests, and after the reading of some letters, delivered his Presidential address, " The American Engineer of To-day."

The second session, held on Wednesday morning, February 17, was devoted to the reading and discussion of the papers on iron and steel.

The following papers were presented by the authors:

Specifications for Cast Iron and Finished Castings, by Dr. Richard Moldenke, New York City.

Chemical Specifications for Pig Iron, by Edgar S. Cook, Pottstown, Pa.

Specifications for Testing Cast Iron, by Henry Souther, Hartford, Conn.

The following papers were presented in printed form:

Standard Specifications for Pig Iron and Iron Products, by the Sub-Committee of the American Society for Testing Materials.

Note on the Further Discussion of the Physics of Cast Iron, by William R. Webster, Philadelphia, Pa.

Note on the Physics of Cast Iron, by Richard Moldenke, New York City.

Specifications for Pig Iron and Iron Castings, by Robert Job, Reading, Pa.

Standardization of the Specifications for Cast Iron and Steel, by William R. Webster and Edgar Marburg, Philadelphia, Pa.

Specifications for Steel Rails, by Robert W. Hunt, Chicago, Ill.

A Decade in American Blast-Furnace Practice, by F. L. Grammer, Baltimore, Md.

Direct-Metal and Cupola-Metal Iron Castings, by Thomas D. West, Sharpsville, Pa.

Stock-Distribution and its Relation to the Life of a Blast-Furnace Lining, by David Baker, Philadelphia, Pa.

The following papers were read by title for subsequent publication:

Specifications for Locomotive Cylinders, by Walter Wood, Philadelphia, Pa.

Specifications for Cast Iron, by C. R. Baird, Philadelphia, Pa.

Specifications for Car-Wheels, by Dr. Charles B. Dudley, Altoona, Pa.

Specifications for Malleable Cast Iron, by Stanley G. Flagg, Jr., Philadelphia, Pa.

The third session was held on Wednesday afternoon, February 17.

The following papers were presented in oral abstract by the authors:

Specifications for Iron Pipe, by Walter Wood, Philadelphia, Pa.

The Mobility of Molecules of Cast Iron, by Alexander E. Outerbridge, Jr., Philadelphia, Pa. (This paper was illustrated by several interesting specimens of cast iron, which had been increased in volume up to 46 per cent by the treatment described.)

From the report of the Council, we extract the following interesting statements:

After the death of Mr. R. P. Rothwell, one of the founders and at a later date, President, of the Institute, his private library of books on engineering was purchased by Mr. John Hays Hammond, and presented to the Institute in memory of Mr. Alfred Raymond, the son and (at the time of his death) editorial assistant of the Secretary.

After the death of Mr. Clarence King, his private library of books on geology, etc., was similarly purchased and presented by Mr. Hammond.

To these generous contributions Dr. R. W. Raymond, Secretary of the Institute, added the gift of his own private library of books on mining, metallurgy, etc.

These three collections were added to the collections of books of reference, sets of periodicals, etc., already in the Secretary's office, the separate volumes being simply marked by a bookplate as presented in memory of Alfred Raymond.

Subsequently, upon the death of Mr. William Van Slooten, a

member of the Institute, his widow presented to the Institute his private library of works on engineering.

It is interesting to note that, among the thousands of volumes thus donated from different sources, there were only a couple of hundred duplicates. Mr. Rothwell's library was rich in French, Dr. Raymond's in German, and Mr. Van Slooten's in English and American, authorities; while that of Mr. King was extremely valuable in the sphere of geology, rather than engineering proper.

The most important event of the year, in its bearing upon the future history of the Institute, was the proposal by Mr. Andrew Carnegie, a member of many years' standing, to erect a suitable building for the use of national American engineering societies. The following statement of the proceedings of the Council with reference to this plan, although already made known by circular, is here reprinted, in order to place it permanently on record in the " Transactions":

In February, 1903, Mr. Carnegie wrote the following letter:

" New York, February 14, 1903.

" *Gentlemen American Society Civil Engineers, American Society Mechanical Engineers, American Institute Mining Engineers, American Institute Electrical Engineers and the Engineers' Club:*

" It will give me great pleasure to give, say, one million dollars to erect a suitable union building for you all, as the same may be needed.

" With best wishes, truly yours,

" ANDREW CARNEGIE."

In addition to this munificent gift (afterwards increased to $1,500,000), Mr. Carnegie undertook to advance the cost of the land required, and has already paid for that purpose a large sum.

The Committee of fifteen members appointed by these various Engineering Societies to consider Mr. Carnegie's proposal reported as follows:

### REPORT

The general committee of fifteen — five representatives from each of the beneficiaries under Mr. Carnegie's proposi-

tion — has had numerous meetings during the past year. Sub-committees have been formed for handling certain details; one to study carefully the question, how the building is to be held for the benefit of the four engineering societies; the Club building being kept separate, designed, built and maintained by the Club alone, without interference on the part of any of the engineering societies. Another sub-committee has had charge of the question of employing architects and designing the engineering building.

Upon its being demonstrated to Mr. Carnegie that the Civil Engineers were hesitant about joining us, for fear that they would not have adequate quarters, but that this difficulty could be overcome if the building were larger, Mr. Carnegie in writing obligated himself to increase his gift, previously stated at one million dollars, to one million five hundred thousand dollars. Upon its being further shown to Mr. Carnegie that the Civil Engineers feared lest tall buildings on either side of the union engineering building might cut off its light, he voluntarily offered to buy adjoining property, say fifty feet on each side, and put upon it a perpetual restriction that no structure should be erected upon it exceeding five stories in height.

The four engineering societies have each taken such steps as were necessary to enable them to accept the gift and to occupy their respective portion of the building when erected, excepting only the Society of Civil Engineers, which has put the question to a postal-card vote of its members, which vote will be received and counted during the first week in March.

Mr. Carnegie has intimated very strongly that the object of his benefaction was to demonstrate to the world the spirit of reciprocity and coöperation which pervaded American technical men, a spirit which he found lacking in Great Britain, where, as he put it, " each engineer is apt to be an island."

There has been some misapprehension lest what was intended by the occupancy of a union building was some sort of federation of engineering societies whereby each would lose its identity. Nothing of this kind has been thought of or suggested, so far as I am aware. While each society will contribute its share of the expenses and receive *pro rata* — upon some proper basis — its share of revenue, if any there be, from the building, each will preserve its integrity, occupying separate floors of the building, having separate library, alcoves and meeting-rooms, but having

the right, under equitable provisions, to make use of the large general auditorium and the large general library.

The Committee on Organization proposes that a special Act, incorporating a committee to administer the engineering building, shall be obtained from the New York State Legislature. This committee to consist of, say, four members, one each from the participating engineering organizations.

At this time everything is waiting for the decision of the Civil Engineers, for Mr. Carnegie, having done all that was possible to induce all the societies to join, has intimated a strong probability that he would decide to withdraw his offer if any one of the societies should decide to stay out.

ALBERT R. LEDOUX.
Chairman of the Carnegie Conference Committee of the Institute.

The Council reported a membership on December 31, 1903, of 3,505 against 3,267 on December 31, 1902, a gain of 238.

The report of the Scrutineers was received, and the result was announced by the President, as follows:

President, James Gayley, New York City.

Vice-President (to serve two years), Julian Kennedy, Pittsburg, Pa., Charles D. Walcott, Washington, D. C., George W. Maynard, New York City.

Managers (to serve three years), Frederick L. Grammer, Baltimore, Md., Charles H. Snow, New York City, Joseph Hartshorne, Pottstown, Pa.

Treasurer, Frank Lyman, New York City.

Secretary, Rossiter W. Raymond, New York City.

Mr. James Gayley, the President elect, was introduced by President Ledoux, and, in brief appropriate remarks, accepted the honor and responsibility of the office.

The meeting was then adjourned, with notice that formal supplementary sessions might be held during the pending excursion of many of the members to Cuba, Porto Rico, etc.

## NOTE ON THE FURTHER DISCUSSION OF THE PHYSICS OF CAST IRON*

By WILLIAM R. WEBSTER

Philadelphia, Pennsylvania

A T the Florida meeting of the Institute, in March, 1895, I presented a brief " Note on the Proposed Scheme for the Study of the Physics of Cast Iron,"† giving an outline which, for convenience of reference, I here repeat.

### Suggested Lines for Discussion and Investigation

I. — Correspondence between chemical composition and melting-point, fluidity shrinkage, fracture, chill, micro-structure, and other physical properties.

II. — Influence of :

1. Cupola-mixture, use of steel and other scrap, oxidized or clean material
2. Manner of melting flux, etc.
3. Casting temperature
4. Manner of handling melted metal and method of casting
5. Size and form of casting
6. Kind of mold, green sand (under different conditions of ramming, amount of moisture, and skin-dried), dry sand, loam, and chills
7. Rate and mode of cooling castings
8. Manner and temperature of heating for annealing
9. Additions of nickel or aluminum

on

A. Fracture.
B. Micro-structure.
C. Physical properties.
D. Shrinkage.
E. Chill.
F. Residual stress.
G. Condition and quantity of carbon and other elements.

III. — Segregation as affected by : 1. Composition ; 2. Casting temperature; 3. Rate of cooling ; 4. Size and shape of casting.

IV. — Blow-holes, their volume and position as affected by : 1. Composition; 2. Casting temperature ; 3. Casting pressure ; 4. Rate of cooling ; 5. Size and shape of casting ; 6. Special additions.

It was hoped that a discussion might thus be elicited, similar in interest and value to the discussion of the physics of steel, which had been so widely and gratefully welcomed by students and practitioners in that department. That this hope was not disappointed is abundantly shown by the contributions to our " Transactions," under the head of " Physics of Cast Iron," of

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* Atlantic City Meeting of the American Institute of Mining Engineers, February, 1904.

† "Transactions," xxv., 964.

Messrs. F. E. Thompson, Pottstown, Pa. (xxv., 964); S. M. Vauclain, Baldwin Locomotive Works, Philadelphia, Pa. (xxv., 967); H. V. Wille, Philadelphia, Pa. (xxv., 969); C. R. Baird & Co., Philadelphia, Pa. (xxv., 971, and xxvi., 997); Thomas D. West, Sharpsville, Pa. (xxv., 972); William C. Henderson, Philadelphia, Pa. (xxv., 974); F. Schumann, Tacony Iron & Metal Co., Philadelphia, Pa. (xxv., 975); E. D. Estrada, Philadelphia, Pa. (xxv., 979); Asa W. Whitney, Philadelphia, Pa. (xxv., 980, and xxvi., 104); Henry D. Hibbard, Highbridge, N. J. (xxv., 988); Prof. R. C. Carpenter, Ithaca, N. Y. (xxvi., 1002); William Kent, Passaic, N. J. (xxvi., 1014); Leonard Waldo, Bridgeport, Conn. (xxvi., 1017); George Morison, Chicago, Ill. (xxvi., 1019); A. E. Outerbridge, Jr., Philadelphia, Pa. (xxvi., 1019, 1023); David Townsend, Philadelphia, Pa. (xxvi., 1021).

To these should be added the separate papers, contained in vol. xxvi., of Messrs. Thomas D. West, A. J. Rossi, and Alexander E. Outerbridge, Jr., and the paper of Dr. Persifor Frazer (xxviii., 613) on " The Kytchtym Medal," and the notable discussion thereof (xxviii., 848).

For five years past, however, our " Transactions " have contained little on this subject; and having been requested by the Council to aid in an attempt to revive the interesting discussion, I have thought that I could not do better than repeat the course which before proved so successful. I have, therefore, urged those who took part at that time to contribute their present views, recent investigations, and any other statements which they may deem appropriate, in order to bring the matter up to date. I trust that others also will give their assistance, and especially that those who have been working on the preparation of various commercial specifications for cast iron, methods of testing, etc., will present such specifications for discussion, and give the reasons and methods which led to their adoption.

A point of peculiar modern importance is the classification of pig iron by its chemical analysis, which involves, of course, the relation between its chemical constitution and physical properties. Since our former discussion, the use of machine-cast sandless pig iron has forced the foundrymen to give up, to a large extent, the grading of the pig by fracture and to depend on the chemical analysis alone. This, in turn, has brought them to rely on the relation between the chemical constitution of the mixture

and the physical properties of the finished casting. They are also now more inclined to discuss the information they have acquired on these subjects, and to feel that they will be well repaid by the assistance received from such an interchange of ideas.

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## NOTES ON THE PHYSICS OF CAST IRON*

### By RICHARD MOLDENKE
#### New York City

I N crowding the recent mass of work on the physics of cast iron into the compass of a short review, I cannot do better than to follow the lines of Mr. W. R. Webster's suggestion made at the Florida meeting of the Institute, March, 1895.† The classification of the properties of the metal, and the influences to which it is subjected during the various processes it undergoes, is quite complete, and as Mr. Webster gives it again in full in another paper before this meeting, a simple reference to it now will be sufficient.

I. *Correspondence Between Chemical Composition, and Melting Point, Fluidity, Shrinkage, Fracture, Chill, Micro-Structure, and other Physical Properties.*

*Melting Point.* — The melting point of cast iron had long been a subject of controversy among foundrymen. They knew that a hard iron melted faster than a soft one, but this effect was occasionally disputed, and the reasons given were unsatisfactory, but could not be well controverted. It was my good fortune to take the actual melting temperatures of some 70 pig irons and castings, the Le Chatelier pyrometer, suitably protected, being intro-

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* Atlantic City Meeting of the American Institute of Mining Engineers, February, 1904.
† "Transactions" xxv., p. 84.

duced into the interior, and the iron melted off in a specially-constructed cupola. The irons had been previously analyzed by taking the borings at the point of the introducing the thermo-couple. The results show a regularly ascending of scale of melting temperatures as the amount of combined carbon decreased. That is, perfect white iron melted at the lowest temperature, and gray iron containing hardly a sign of carbon in combination resisted the melting heat the longest. This effect means that a 4-per cent steel, if we may call a white iron thus, which has no graphite in admixture, melted faster than a, say, 0.10-carbon steel with nearly four per cent graphite mechanically intermixed, or gray iron. This conclusion seems natural in the light of our knowledge of steel, and indeed, it seems to have settled the matter effectually.

*Fluidity.* — The fluidity of a cast iron is known to depend in some measure upon the phosphorus-content, yet little has been done in this field, the experience apparently having been accepted without question. It were well if a series of experiments could be made to confirm the assumption, which might throw additional light on the subject of value in other directions. Oxidation has an important bearing on the fluidity of the metal, and a bath of highly oxidized metal loses its fluidity so rapidly by the lowering of the temperature resulting from tapping and carrying, that the ladles " skull " and the molds are short-poured ; an effect entirely independent from the phosphorus-content of the metal, be it high or low.

*Shrinkage and Contraction.* — On the question of contraction, and its relation to the chemical composition, no general law can be laid down. A dead white iron is supposed to contract a little over 0.25 in. to the foot; a dead gray iron, a little under 0.125 in. to the foot. Between these two typical extremes in cast iron there is a large series of commercial products in which the amount of contraction shades from one to the other. Unfortunately for methods of measuring contraction and judging the composition therefrom, the casting temperature plays sad havoc with the results. A hot iron always has a greater contraction than if the metal were held in the ladle for some time before pouring. Just why this is the case has not been definitely settled. The distinction between contraction and shrinkage should be noted. These terms are invariably confounded by the gray-iron founder. Shrinkage

takes place at the moment of set, the metal becoming spongy. Contraction takes place after the moment of set, the red-hot casting slowly contracting as it cools.

*Fracture.* — The fracture of an iron is directly related to its chemical composition; yet it is no criterion of what the iron will be after remelting and casting under normal conditions. The furnaceman who gets more money for the large-grained, black, open-fractured iron than for the close and light gray variety, naturally wants to make only the former, hence all kinds of methods are adopted to achieve this result. Look over the metal yard of a foundry and note the heavy sections that pig iron has come to assume. Also the signs of the sand which has been thrown on the molten metal in order to retard the cooling of the cast. The machine-cast pig iron, which is now beginning to find its way more and more into the foundry, has helped to remove the last vestige of prejudice concerning the fracture-question from the otherwise enlightened founder. But long before this machine-cast metal was sold to the founder in large quantities, he had come to realize that the chemical specification alone was the best safeguard. To-day the founder who buys by grade and demands a given fracture gets his material, having the desired appearance, but with it, in addition, a nice assortment of compositions which would soon bring him to grief were it not for the custom to keep a lot of irons always at hand and in the mixture. The founder who knows, in the meantime, gets the pick of the market.

*Chill.* — The hotter the iron is cast, the deeper will be the chill. Unquestionably, the proportion of combined carbon left in a casting is at the bottom of this phenomenon, but why the deeper chill should go with the hotter iron, when exactly the opposite is expected, is a question still unanswered.

II. 1. *Cupola-Mixture.* — For the cupola-mixture, and for that matter the furnace-mixture also, the addition of steel-scrap has done much to improve the quality of the castings made in this way. It remains cast iron just the same, but the total carbon has been lowered considerably, which, with a practically constant combined-carbon content, means the reduction of the graphite separated out, or, in other words, fewer planes of weakness in the metal. The fracture becomes lighter, as a consequence, and the contraction greater. If good results are wanted, about 25 per cent of steel-scrap is the maximum proportion allowable in the cupola.

Above this quantity great irregularity in the product is observed. For furnace-work, up to 30 per cent can be used; but even here the effect of oxidation becomes quite marked, shrinkage in the interior of the casting too pronounced, residual strains serious, and the molding-losses too much to permit. Nevertheless, the moderate use of steel is a good thing in the foundry, and should be encouraged.

When oxidized material is charged, that is to say, burnt iron grate-bars, salamanders, and the like, and, to a lesser extent, rusty material, the product will always be bad and were better left alone and put into sash weights. Scrap, very rusty, is not detrimental if some silico-spiegel or ferro-manganese is charged with the heat. In the absence of which, however, plenty of limestone and a little fluor-spar to promote fluidity will be beneficial.

II. 2. *Manner of Melting in the Foundry.* — Although the modern high-pressure production tends to injure the metal, blast pressures are climbing, and coke is sacrificed to save time, not so much in order to crowd the pouring to the end of the day for convenience, but because labor exactions have made it necessary to take away from the men as much as possible any excuse for loafing, very little molding being done after the iron begins to run. As our pig irons are not any too good to start with, and the melting processes of the foundry, if anything, injure them still further, a change to conditions which would allow the iron to melt slowly, and be tapped out periodically during the day, would be welcomed. In those cases where the casting is continuous, greater pains can be taken with the charging, fluxing, etc., and possibly in the future the iron may be tapped into a mixing ladle as fast as melted and thence taken to the molds. In this way the iron would not remain in contact with the fuel very long and would have better properties. The European method is to be commended in this respect.

The effect of melting upon the physical structure of the iron is fairly well marked in its subsequent manipulation in the machine-shop. Good hot iron in the cupola will not take up as much sulphur as will a cold heat. Hence, a difference in the structure is quickly noticed in planing-up a casting. In general foundry-work it is good practice to melt very hot, and to hold the iron until cool enough to cast safely. For special work this will not always hold true, as will be shown later.

With a large heat poor slagging-out means dirty iron. At first it does not matter, but after ten tons or more have been melted, the slag begins to be troublesome. It is better, therefore, to provide a slag-spout and to use it. The result will quickly be noted by a reduced scrap-pile in the trimming-room. Nothing is paid back so disagreeably as carelessness on the charging platform.

The melting process naturally has an effect on the composition. Manganese and silicon are burned out to some extent, sulphur is unfortunately increased, and the total carbon in the charge will be increased or diminished according to circumstances. There is a tendency to hold a saturation point fixed by the percentage of silicon present. If the total carbon is below this, it will be increased; if above, it may be diminished. In general, the less the silicon, the more the tendency of the metal to take up carbon.

II. 3. *Casting Temperature.* — The casting temperature is a very important item, for the reason that, while one class of work requires very cold iron, another must have it " piping hot." It becomes really a question of surface excellence for the casting to be poured. In one case good chilling effects must be obtained, together with absence of the slightest pin-holes, as for instance in the chilled roll, where the metal should be cast as hot as the chills can bear it without fusing. In another case it may be necessary to have some machining done; in this case the metal is poured cold, in order not to burn the sand of the mold to the casting. To return to the chilled roll, if this be cast with metal too cold, the casting sets too quickly, and the enormous casting-strains produced in the rim from its contraction upon a solidified interior always mean trouble. Take the coefficient of expansion of white iron and note just how many inches this makes on a roll 36 in. in diameter cooled from about 2,000° F. to ordinary temperatures. The inches thus lost in the circumference must be taken up by a suitable stretch in the metal there, and in the case of a cold pour a rupture along the whole face of the casting will result. If, on the other hand, the roll be cast with very hot metal, the rim is at once chilled and set, while the interior is still molten; and by the time the interior sets the solid rim has shrunk to some extent, and at least is sufficiently strong to withstand the internal resistance to final contraction without tearing apart.

II. 5. *Size and Form of Casting.* — The thickness of the iron in a casting bears a direct relation to the rate of cooling, and

consequently on its physical structure, as already explained. Therefore (in making mixtures) it is necessary to keep in mind the thin parts as well as the thick. Thus a heavy dynamo-frame, for which a mixture containing 1.75 per cent silicon would be just right, may have a small thin bracket which requires machining. The silicon, therefore, must be raised to 2.15 per cent in order to accommodate this part to the proper composition, otherwise the machine-shop work may cost more than the additional price paid for the softer iron.

II. 6. *Kind of Mold, etc.* — The mold itself also has an effect, loam- and dry-sand methods allowing hotter iron to be used with good surface results in those cases in which green sand would give a badly scabbed or skin-hardened casting. With a very heavy body, the effect is not so marked, for the reason that there is a subsequent annealing proceeding from within outward.

II. 8. *Manner and Temperature of Annealing.* — The annealing of castings is a study by itself, of which we have still much to learn. The process consists in heating the material to be annealed to a high temperature and then slowly cooling it. Where the sulphur-content is fairly low, and the edges of small castings are too hard for rapid machining, annealing them will be beneficial. With higher sulphur it often becomes a question solely of scrapping the lot. Between the annealing process applied to malleable castings on the one hand, and gray iron on the other, undoubtedly the special form of free carbon, known as temper carbon, will be found to play an important part also in the gray-iron end of the foundry industry.

II. 9. *Additions of Nickel or Aluminum.* — The use of aluminum in the foundry is becoming more limited than it was, for the reason that it has been found to be injurious to the harder irons; that is, for hard irons the remarkable property possessed by the light metal of throwing out the graphite militates against its usefulness. For the soft varieties of iron, a small quantity ôf aluminum, added when gases are feared, is very good, but as above mentioned, proper precautions in melting should make the need of this addition unnecessary. On the other hand, the use of titanium-iron alloys is to be commended, because the titanium reacts directly with any oxygen or nitrogen present in solution, and, as a consequence, a purification takes place which cannot be overvalued. Increasing the strength of an iron 20 per cent, without remaining behind as an integral part of the metal, seems to be

the function of this new candidate for foundry favors. With regard to the addition of other metals, such as nickel, cobalt, etc., but little is heard about them in the foundry. These metals, or their alloys, are too expensive, and consequently it is more profitable to use steel castings for material of a strength greater than that of cast iron.

III. *Segregation.* — The subject of segregation in cast iron is one which could well be studied more fully. Apart from the formation of graphite, which can be considered a sort of distributed segregation, we know very little of the peculiarities of iron phosphide, and still less of iron sulphide, so far as their tendencies to segregate are concerned. On account of the lower melting point of iron phosphide, globules of iron are occasionally found with a higher phosphorus-content than the rest of the metal, which have been pushed out of the main body, or have entered into the blow-holes in the interior of the casting. By far the most important subject for study is the segregation of the sulphides, and in this field the microscope will eventually prove itself most valuable. Up to the present time this indispensable adjunct to the laboratory has done little for cast iron, partly because the methods of determining constituents other than carbon are practically wanting and also because our steel experts know very little of cast iron from actual practice.

IV. *Blow-Holes.* — With good molding, good iron and good melting, blow-holes should not exist, and, generally speaking, they result from errors of manipulation. Where the sand has been rammed too hard, or the venting is imperfect, air is often imprisoned and sent about in bubbles, usually covered over by a skin of iron. If a rather large blow-hole exists near the surface, the iron can often be " burned on " and the casting saved. The blow-holes to be feared are the small gas-pockets, such as those appearing on the surface of a chilled roll, practically pin-head in size, but nevertheless sufficient to condemn the work. In this case the metal is oxidized to an extent that gas is liberated at the moment of set, and becomes imprisoned very near the surface, often causing disastrous results. The trouble with blow-holes is usually confined to the low-silicon range of cast irons, and were it not for the fact that the addition of aluminum promotes the formation of graphite, this metal would form a valuable corrective. We must look to the future for relief, possible with ferro-titanium alloys, or the ferro-compounds of such metals as magnesium. If a large

furnace heat gives indications of being heavily charged with oxides, the only safe way to act is to add plenty of ferro-silicon, rabble thoroughly, and cast all of the metal into pigs, which can be subsequently fed into the regular mixture in small amounts until the supply of this unwelcome metal is used up.

The future of our studies along the lines indicated above seems to lie in the devising of methods to control the chemical composition of cast iron in cupola and furnace, irrespective of the nature of the pig and scrap charged. Thus we should be able to eliminate sulphur, and perhaps phosphorus, at will. We should also be able to remove the last traces of oxidation, which has been due either to the blast-furnace or to the cupola-furnace at some previous smelting. With those desiderata the field for the make of foundry pig iron will be greatly broadened and many an iron ore, now unsalable, would find its way into the market, to the lasting benefit of world's mineral resources.

## THE MOBILITY OF MOLECULES OF CAST IRON*

(Supplementing the Paper under this Title in " Transactions," xxvi., p. 176)

By A. E. OUTERBRIDGE, JR.
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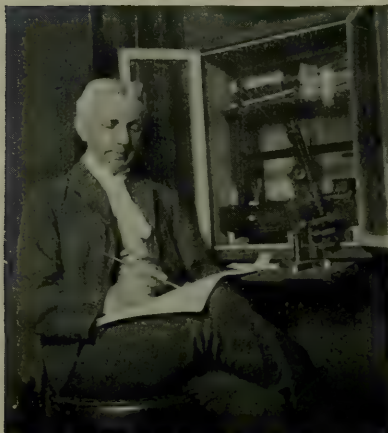
I HAD the honor to present to the American Institute of Mining Engineers at the Pittsburg meeting, February, 1896, a paper having the foregoing title, in which I said: " It has generally been accepted as a fact that cast iron, under the influence of repeated shocks, becomes brittle, and will finally break under a blow which otherwise it would have withstood. It

* Atlantic City Meeting of the American Institute of Mining Engineers, February, 1904.

will probably surprise metallurgists, therefore, to learn that experiment disproves the supposed fact, and establishes exactly the opposite.

"The result of about a thousand tests of bars of cast iron of all grades, from the softest foundry mixtures to the strongest car-wheel metal, enables me to assert with confidence that, within limits, cast iron is materially strengthened by subjection to repeated shocks or blows."

Three tables were appended showing increase of strength and resilience of test-bars which had been subjected to repeated shocks or vibrations, in various ways, as compared with companion bars cast in the same molds, from the same ladles of iron, not so treated. The largest gain in strength recorded in these tables was very nearly 19 per cent.

The surprising statements immediately attracted the universal notice of founders and engineers, both in this country and in Europe; many tests were made and recorded in technical journals, which not only corroborated the original claims but largely exceeded them.

The Franklin Institute appointed a committee of experts to investigate the subject. This committee cast a large number of bars, half of which were subjected to mechanical shocks, the remaining half being untreated. Their report (No. 1910), dated May 5, 1897, was published in the "Journal of the Franklin Institute," July, 1898, and in the table of tests, covering 82 bars, the maximum increase in strength of treated bars — as compared with untreated companion bars, free from defects — was shown to be 40 per cent, and the maximum increase in deflection was 41 per cent.

Two important practical results have since been developed from the publication of these new principles: one has been a great increase in the practice of tumbling castings, wherever practicable, instead of pickling them, as was formerly frequently done, to remove sand burnt into the surface of such castings, for subsequent investigations have shown that test-bars and other castings which have been pickled are invariably weaker than companion bars or castings not pickled, the decrease in strength averaging, in the case of test-bars pickled in sulphuric acid and water, about ten per cent, while castings cleaned in the tumbling barrel are invariably much stronger than before treatment.

In England, tumbling barrels of unusually large size have been constructed provided with two rates of speed, in order that the full benefit of increase of strength due to mechanical shocks upon castings may be utilized.

In an instructive article, one of a series, by Mr. Robert Buchanan, an English writer, on " Foundry Methods in the Twentieth Century," printed in the " Engineering Magazine," May, 1903, a photographic illustration is shown of such an apparatus, and testimony of a highly gratifying nature is given of the practical value of these discoveries.

The second important result of the publication of these heretofore unobserved properties of cast iron has been the incorporation in some specifications for castings of a clause stipulating that " the test-bars shall not be rumbled or otherwise treated, being simply brushed off before testing." The latest instance of the kind may be found in the " Specifications for Gray Iron Castings," recently formulated by a committee of the American Society for Testing Materials, of which Mr. Walter Wood is chairman.

The concluding sentence of my original paper, presented to the American Institute of Mining Engineers in February, 1896, was as follows:

" I have suggested and adopted throughout this paper the hypothesis of the mobility of the molecules of cast iron, resulting in an effect similar, or analogous, to the effect of annealing by heat, because it seems to be warranted by the facts developed by the experiments described; it is, of course, possible, in our *à priori* ignorance of the laws governing atoms and molecules, that the theory may not be correct, but the tentative propounding of a probable hypothesis, by inciting to a more extended course of experiment along different related lines of investigation, often leads to establishing or disproving the theory, and thus adds to our stock of positive knowledge."

Professor Ledebur investigated both the facts and the theory advanced by me to explain these facts, and, while admitting the facts, he attributes the astonishing gains in strength to " stretching of the skin of castings," which, he thinks, has gotten into a state of tension due to the unequal cooling of the test-bar or other casting.

Before the publication of the original paper on " The Molecular Mobility of Cast Iron," I began a long series of investigations

from an entirely different point of view, which have, I think, re-
sulted in the discovery of some hitherto unobserved properties of
cast iron (or if observed at all prior to this announcement they
have not been properly understood), as surprising and unex-
pected as were the facts contained in the first communication, all
tending, moreover, to establish the correctness of the theory then
advanced regarding the mobility of molecules of cast iron.

In accordance with the request of the Secretary of the Amer-
ican Institute of Mining Engineers, received through Mr. Wm.
R. Webster, under date of November 5, 1903, " that you will take
up the subject where you left off in the former discussion and
give us the benefit of your present views," I now have the honor
to offer for your inspection some test-bars of cast iron, together
with photographs of castings, bars of steel and wrought iron, and
photo-micrographs of sections of such bars, showing remarkable
structural changes due to certain treatment described herein.

The two test-bars of gray cast iron, submitted herewith, were
cast side by side in one mold from one hand-ladle of iron from
one runner; the molds were exactly 15 in. long and 1 in. square
section, the ends being formed by iron yokes (machined to 15 in.)
inserted in the mold, in order to avoid any possible irregularity in
length due to the ordinary method of rapping patterns before re-
moving them from the mold.

When cleaned, the shrinkage of the bars was measured by in-
serting a hardened steel wedge between the ends of the bars and a
master yoke, kept for the purpose in a suitable frame, the wedge
being graduated so as to readily show thousandths of an inch.
(See Fig. 2.)   There was a difference of but 0.003 in. in length
between the two bars; they measured practically 14 13-16 in. long
and 1 in. square section.   One bar remains just as it was cast, the
other has been caused *to grow gradually in cubic dimensions* while
in the solid state, until, at the present time, it is 16½ in. long and
1⅛ in. section.

An examination of the milled surface of a portion of the en-
larged bar will show beautifully fine-grained metal with smooth
finish, having apparently lost none of its metallic qualities, not-
withstanding the extraordinarily large permanent increase in
cubical dimensions, exceeding 40 per cent of the original bulk.
The original dimensions of bars Nos. 1 and 2 were 14 13-16 in.
by 1 in. by 1 in., equivalent to 14.8125 cu. in., and the new dimen-

sions (bar No. 1) were 16.5 in. by 1.125 in. by 1.125 in., equivalent to 20.8828 cu. in., which showed an increase in volume of 40.98 per cent. This enlarged bar weighed precisely the same as before treatment, but its specific gravity was, of course, considerably less. The actual specific gravity of a piece of a similar test-bar before treatment was found to be 7.13, giving, by calculation, a weight of 444.75 lb. per cu. ft.; the specific gravity of a piece of the same bar, after having been caused to grow in cubical dimensions about 30 per cent, was found to be 6.01, giving a weight of 375.5 lb. per cu. ft., a difference of 69.25 lb. per cu. ft.

Similar bars of wrought iron, soft steel (carbon 0.25 per cent), tool steel (carbon 1.25 per cent), and cast steel, treated in precisely the same manner as the expanded cast iron bars, all show a slight contraction, equivalent to about 0.125 in. to the foot.

These curious experiments were commenced in 1896, and early in 1897 the editor of " The Foundry," Mr. John A. Penton, saw some of the enlarged bars in my laboratory and asked permission to print an editorial note in regard to the matter. The following extract from the editorial columns of " The Foundry," April, 1897, entitled " Making Castings Grow," will explain the method adopted at that time for increasing the cubical dimensions of castings without changing their form, weight, or chemical constituents.

" It may be interesting to know that a metallurgical friend of ours, Mr. Outerbridge, of Philadelphia, has been cultivating a very peculiar plant for nearly a year past, which has been steadily growing in the arid soil of a foundry and has not yet reached full maturity. The plant we refer to is a cast iron test-bar.

" Two bars were cast side by side in one mold from patterns 1 in. square and 15 in. long, between the ends of iron yokes. The bars, when cold, measured almost the same length, differing only 0.001 in.

" When placed within the yoke and carefully measured with a graduated steel wedge, the shrinkage of one bar was found to be 0.184 in. and the other 0.185 in.

" The shorter bar was then heated by pouring about 10 lb. molten cast iron (of the same composition) over it, the bar forming the bottom of an open mold.

" On the following day the bar was again measured, and now showed a shrinkage of only 0.15 in. The experiment was repeated, and on a second test the steel wedge showed a space of 0.128 in. between the bar and the yoke. Six times this test

was repeated, each time the bar growing longer, and, on the seventh heating, it would no longer fit between the ends of the yoke, showing that the bar had now grown to the full length of the mold in which the molten iron was cast. In other words, the natural shrinkage of the metal had been entirely eliminated by the gradual increase in length due to successive heatings.

" The bar increased also visibly in thickness, and after the third heating it became crooked; its position was then reversed each time that it was placed in the mold for heating, in order to obviate this tendency.

" After 12 successive heatings and coolings the bar measured a full quarter of an inch longer than its companion, and also lost its tendency to become crooked. After 15 repetitions the bar increased less than before at each heating, and though it had not finished growing, curiosity to ascertain the effect upon the strength of the metal prompted the experimenter to break both bars upon the testing machine. The untreated bar broke under a strain of 2,150 lb. (transverse or cross-section stress) and showed a deflection of 0.15 in.; the metal was open-grained, soft, foundry-iron. The companion bar, which had been subjected to 15 alternate heatings and coolings, as described, broke at 1,250 lb. and showed a deflection of 0.1 in. . . . This curious experiment with the ' growing casting,' which we have described, is not only interesting as a novel investigation, but it casts new light upon the cause of molecular changes in cast iron when subjected to alternate heating and cooling, and also furnishes valuable information as to the serious effect upon the strength."

Although complete chemical analyses of both bars were not made, certain chemical tests indicated clearly that the only change in constituents was that a very small amount of combined carbon in this soft metal was converted into graphite by the annealing process. This increase of free carbon (the total carbon remaining the same as before treatment) does not account in any way for the enlargement of the bar. The explanation which I offered at the time and have since corroborated by very many tests, made under varying conditions, is, that the crystals of cast iron, unlike those of steel or wrought iron, are capable of inter-molecular movement within a wide range, the full extent of which I have not yet ascertained.

In the more recent experiments, where the cubical expansion

of the bar (such as the one exhibited herewith) is more than six times as great as in the bar described in " The Foundry," April, 1897, a different method of heating has been employed, whereby a record of the critical temperature necessary to produce the largest results per heat has been carefully kept.

These bars have been heated in a case-hardening furnace, provided with a pyrometer, at a uniform temperature of about 1,450° F. for a period of about one hour each day; the gas was then turned off and the furnace allowed to cool down slowly over night, the bars being removed in the morning and measured before re-heating.

In order to prevent scaling, or oxidation of the surface, the bars are enclosed in an iron pipe, the ends being stopped with clay.

At first, a temperature not execeeding 1,200° F. was maintained, and under these conditions it was necessary to heat and cool the bars about a hundred times, in order to obtain an increase in cubical dimensions equal to that shown in the bar submitted herewith. By increasing the temperature to about 1,450° F., an increase in length of about 1-16 in. per heat is obtained. The bar submitted for your inspection, which shows an increase over its untreated companion bar of 1 11-16 in. in length and ⅛ in. in cross-section, has been heated and cooled 27 times.

All grades of cast iron do not increase in cubical dimensions equally; soft iron, containing but little combined carbon, increases more rapidly than harder iron containing more combined carbon, while white iron, in which nearly all of the carbon is in the combined form, does not expand sufficiently to overcome the original shrinkage, even after all of the combined carbon has been changed to graphite or rather to that form of free carbon known as " Ledebur's temper carbon " by this annealing process. Wrought iron and steel bars subjected to the same repeated heating and cooling, in a closed tube, have all contracted slightly in cubical dimensions. The average contraction of such bars after about 60 heatings in a closed pipe is ⅛ in. per foot.

In determining the specific gravity of sections about 0.25 in. thick, cut from bars which had been caused to grow in cubical dimensions in the manner stated, a very surprising phenomenon was observed. After weighing a specimen in the air, suspended

by a horsehair from one arm of an analytical balance, the piece
was immersed in a vessel of distilled water. Instantly bubbles
of gas appeared over the entire surface of the metal, rising
through the water in a copious stream, this action continuing
for more than one hour. On removing the specimen after the
bubbling had ceased, drying off the surface-moisture, and re-
weighing, a gain in weight, due to absorption of water in the
pores of the iron, amounting to 0.870 grams was found. In-
vestigation shows that the bubbles are not " occluded gas "
originally entrained, or contained within the metal, but are simply
air which enters to fill the void in the spaces between the
molecules as the bar cools from the red-hot state.

Specimens immersed in gasoline, alcohol, naphtha, and other
liquids, all give off bubbles of air in the same manner; and,
moreover, if a piece of saturated metal be allowed to remain in
a warm room for several hours, the water or other fluid will
gradually evaporate and air will again take its place, so that,
when the specimen is re-immersed, the bubbling is renewed as
actively as before.

As the object was to determine the specific gravity of the
mass, not the average specific gravity of the constituents of the
metal, the simple plan was adopted of coating the specimen with
a thin water-proof varnish before weighing; this protective cover-
ing prevented the escape of air, and ingress of water, during
the process of weighing, while the specimen was suspended in
the vessel of distilled water and the true specific gravity was
thus readily determined.

Notwithstanding the truly astonishing increase in cubical di-
mensions of these cast iron bars, none of them have as yet fin-
ished growing, nor do they show any signs of disintegration.
I am unable, therefore, to define the limits of growth, and the
experiments are still in progress. (See footnote to Fig. 1.)

The fact that there is a loss of tensile and transverse strength
of from 25 to 30 per cent in some of the tests might seem, at
first sight, to put a barrier in the way of practical applications
of these new observations; but such is not the case. Already
several such applications have been suggested and tried with
success. For example, very recently a cast iron pattern of a
" pin cam lever " was made in two halves for a new machine,
and after some expensive machine-work had been put upon the

castings (they were nearly finished), it was discovered that an error had been made, and that the two half patterns were both a quarter of an inch too short and three thirty-seconds of an inch too narrow. These castings were, therefore, useless, and would have been "scrapped" had it not been for the ingenuity
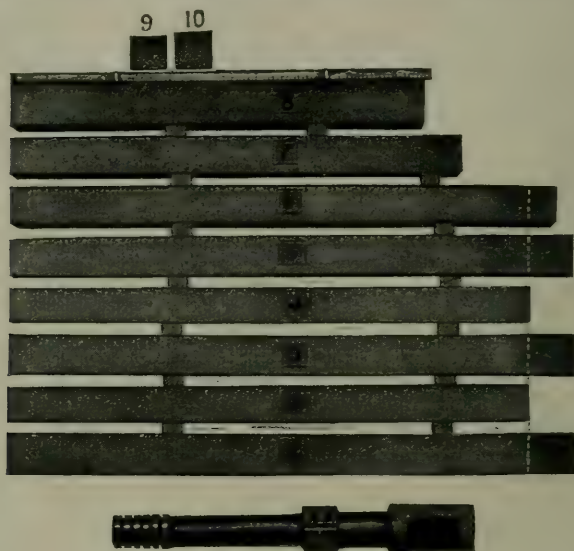


Fig. 1. Expansion of Cast Iron Bars by Repeated Heatings.

Bar No. 1. Total expansion, 27 heatings, is $1\frac{11}{16}$ in. in length and $\frac{1}{8}$ in. in each transverse dimension. Bar No. 2. Untreated companion of bar No. 1. Bar No. 3. Total expansion, 27 heatings, is 1.5 in. in length and $\frac{1}{8}$ in. in each transverse dimension. Bar No. 4. Untreated companion of bar No. 3. Bar No. 5. Total expansion, 50 heatings, $1\frac{3}{8}$ in. in length and $\frac{3}{32}$ in. in each transverse dimension. Bar No. 6. Total expansion, 30 heatings, $\frac{3}{4}$ in. in length and $\frac{1}{16}$ in. in each transverse dimension. Bar No. 7. Original length, 12 in. Total expansion, 49 heatings, 1 in. in length and $\frac{1}{8}$ in. in each transverse dimension. Bar No. 8. (Soft steel bar.) Original length, 12 in. Total contraction, 61 heatings, $\frac{1}{8}$ in. per foot. Bars No. 9 and No. 10. Transverse sections of cast iron bars before and after heat-treatment. Total expansion of heated piece was $\frac{3}{32}$ in. in each transverse dimension. Bar No. 11. Cast iron piston having the polished end expanded 0.045 in. by heat-treatment. Bars Nos. 1, 3, 5, 6 and 7 have been chalked at the right hand ends to show the increase in the lateral dimension.

NOTE.—(January 20, 1904.) All treated bars represented in this illustration are now larger than when the photograph was taken. No. 1 has been subjected to 12 additional heatings at 1,450° F., and has become increased to 16.625 in. in length and to 1.1406 by 1.1406 in transverse section, which is equivalent to a total increase in volume of 46 per cent. The last six heatings made no appreciable increase in the size of the bar.

of the operator of the case-hardening furnace, where the experimental test-bars had been heated and expanded, who very successfully elongated and widened these cast iron patterns, without serious warping or twisting, bringing them in three heatings to the required dimensions.

Appended to this paper will be found some small photographs, Figs. 1, 2, 3 and 5, showing castings of various kinds that have been experimentally enlarged by heating and cooling in the manner described. In Fig. 1 a small cast iron piston is shown (No. 11), which had become worn too small for further use, the maximum allowance for wear being 0.008 in. in diameter. In five heatings in a closed tube, to prevent oxidation, the di-



Fig. 2. Expansion of a Cast Iron Bar by Repeated Heatings.

The length of the untreated cast iron bar in the yoke is $14\frac{13}{16}$ in. and the length of its companion bar No. 2, after treatment, is 16.5 in., showing an increase in length of $1\frac{11}{16}$ in. The increase in each transverse dimension is 0.125 in., and the total increase in volume is 40.98 per cent.

ameter of the polished end, showing five grooves, was increased 0.045 in., or more than seven times the amount required to restore it to the original size. The illustration shows the piston as it came from the oven before being re-ground to size. It also shows eight test-bars, seven of cast iron and one of steel, treated in various ways as detailed in the description of the illustration.

Fig. 2 shows an untreated test-bar placed within the iron yoke, the hardened steel wedge in position for measuring the shrinkage. On the table beneath the yoke is shown the companion test-bar, cast of the same dimensions as the other, but expanded 1 11-16 in. in length and $\frac{1}{8}$ in. in cross-section.

Fig. 3 shows a turned pulley, a gear-wheel blank and several bushings and rings of cast iron, some untreated and some subjected to repeated heatings, as described in detail in the footnote to the illustration.

Fig. 4 shows a photo-micrograph of a ground and polished section of an untreated piece of test-bar, and a similarly smoothed and polished section of the same bar after 35 heatings. These
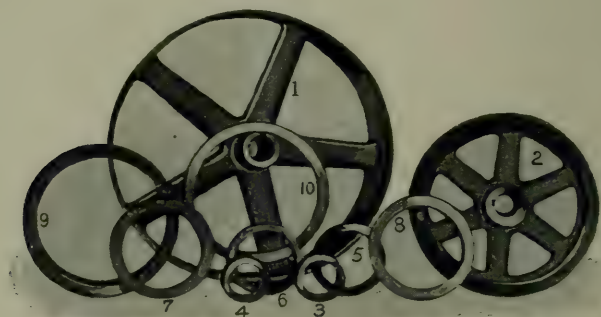


**Fig. 3. Iron Castings Expanded by Repeated Heatings.**

No. 1.  Cast iron pulley (turned) $14\frac{3}{4}$ in. in diameter and $\frac{5}{16}$-in. bore.  Expansion is $\frac{3}{16}$ in. from four heatings.

No. 2.  Blank gear-wheel (turned) $9\frac{3}{16}$ in. in diameter and $1\frac{1}{8}$-in. bore.  Expansion $\frac{1}{16}$ in. from five heatings.

No. 3.  End of small bushing $2\frac{3}{32}$ in. in outside diameter, $1\frac{47}{64}$ in. in inside diameter.  Expansion $\frac{5}{64}$ in. in outside diameter from 20 heatings.

No. 4.  Untreated companion piece of No. 3.

No. 5.  Piece of bushing $3\frac{9}{16}$ in. in outside diameter and 3 in. in inside diameter.  Expansion $\frac{3}{32}$ in. in outside diameter from 15 heats.

No. 6.  Untreated companion piece of No. 5.

No. 7.  Untreated companion piece of No. 8.

No. 8.  Piece of bushing 5 in. in outside diameter and 4 in. in inside diameter.  Expansion $\frac{3}{32}$ in. in outside diameter from 16 heatings.

No. 9.  Piece of bushing $7\frac{7}{16}$ in. in outside diameter and $6\frac{7}{16}$ in. in inside diameter.  Expansion $\frac{1}{4}$ in. in outside diameter from 19 heatings.

photo-micrographs, made by Mr. Job, chemist of the Reading Railroad, show very clearly the change in molecular structure of cast iron, due to alternate heating and cooling.

Fig. 5 shows the expansive effect of heating an iron-casting. The upper illustration is the wooden pattern from which the original iron-casting was formed, and the lower is the same

pattern on which has been superposed the iron-casting that has been expanded by many heatings and coolings during nine months of continuous use. The grating had been laid loosely on the floor of a core-oven, over the flue and nearly ten feet above the top of an anthracite coal fire, far removed from flames.



Untreated.                    Treated.

Magnified Fifty Diameters
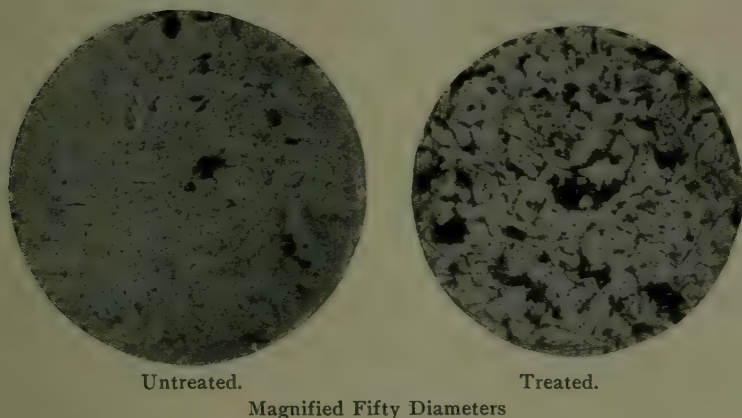
Fig. 4.   Photo-Micrographs of Untreated and Treated Cast Iron.

A careful examination of these photo-micrographs shows a similar arrangement of the crystals in both specimens, the only material difference being the contiguity of the iron particles which have been pushed out in all directions and have not returned to their original positions when cold, thus accounting for the increase in the cubical dimensions of the expanded metal as well as for the ingress of air.

The flue is very much smaller in diameter than the casting. The outside bars (or frame) of the casting, resting on the floor, are, therefore, protected from direct radiation of heat, and, remaining comparatively cool, do not tend to expand. The central portion of those bars which were exposed to the greatest heat expanded both in length and in thickness, and as the ends were held by the non-expanding frame they were forced to assume the curved forms shown in the photograph. The left hand bar of the pattern measured 22¼ in. on the longest side, as shown by the two-foot rule placed in proximity thereto.

The corresponding bar of the casting, measured on the same side, showed an increase in length of 2 1-16 in. or 1.11 in. per foot. The bars also increased 3-16 in. in width in the central

Wooden Pattern.
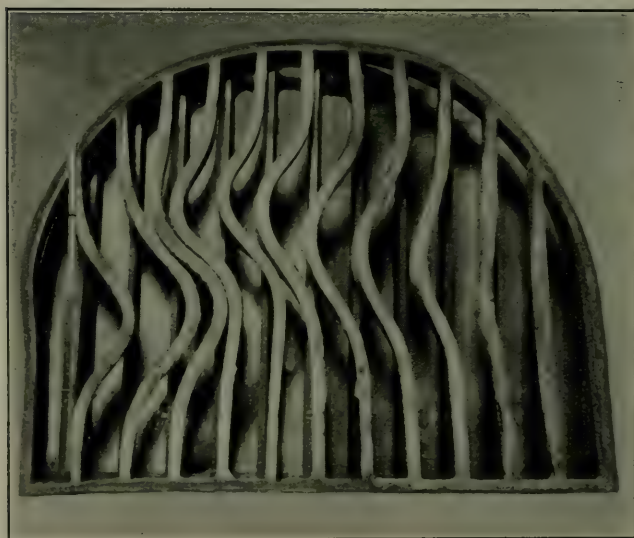


Wooden Pattern and superposed iron-casting made from it.

Fig. 5. Wooden Pattern and Iron-Casting, Showing the Expansive
Effect of Heat.

portion, the difference in thickness of the center and ends, as well as of the bars composing the outside frame, being plainly visible in the illustration.

Steel does not increase in cubic or linear dimensions by such heat-treatment, and it is proposed to have steel-castings made from this pattern to replace four iron-castings, all of which are distorted in a manner similar to the one shown.

It is a question for future consideration, in view of these facts, whether cast steel grate-bars will not eventually replace cast iron ones although the " scaling " of steel due to oxidation and also to absorption of sulphur from fuel is undoubtedly greater than that of cast iron under similar conditions.

Tables I, II, and III give the measurements of various test-bars expanded by heating in closed tubes and in an open fire, and Table IV shows the data of shrinkages of certain wrought iron and steel bars.

Table I. — *Results of Experimental Heatings of Cast Iron Test-Bar. Marked "A" No. 1, November 24, 1903.*

| | Number of Heats | Length | Expansion Since Last Measurement | Total Expansion | Rate of Exp'nsion Per Heat |
|---|---|---|---|---|---|
| | | Inches | Inches | Inches | Inches |
| Before heating . . | . . . | $14\frac{25}{32}$ | . . . | . . . | . . . |
| 1st measurement . . | 10 | $15\frac{1}{16}$ | $\frac{9}{32}$ | $\frac{11}{32}$ | 0.0284 |
| 2d measurement . . | 5 | $15\frac{3}{32}$ | $\frac{3}{32}$ | $\frac{3}{8}$ | 0.0187 |
| 3d measurement . . | 2 | $15\frac{9}{32}$ | $\frac{1}{8}$ | $\frac{1}{2}$ | 0.062 |
| 4th measurement . . | 11 | $15\frac{1}{2}$ | $\frac{7}{32}$ | $\frac{23}{32}$ | 0.0199 |
| 5th measurement . . | 8 | $15\frac{11}{16}$ | $\frac{3}{16}$ | $\frac{29}{32}$ | 0.023 |
| 6th measurement . . | 4 | $15\frac{5}{8}$ | $\frac{3}{16}$ | $1\frac{3}{32}$ | 0.046 |
| 7th measurement . . | 5 | $15\frac{31}{32}$ | $\frac{3}{32}$ | $1\frac{3}{16}$ | 0.0187 |
| 8th measurement . . | 1 | $16\frac{1}{16}$ | $\frac{3}{32}$ | $1\frac{9}{32}$ | 0.0937 |
| 9th measurement . . | 4 | $16\frac{5}{32}$ | $\frac{3}{32}$ | $1\frac{3}{8}$ | 0.0234 |

NOTE. — This bar is one of the regular test-bars cast from first of heat o November 24, 1903. Measured $14\frac{25}{32}$ in. long when cast, and yielded a total expansion for 50 heats of $1\frac{3}{8}$ in. per 15 in., or at the rate of 0.0275 in. per heat.

In this report of progress made in the investigations into the molecular structure of cast iron since my first paper, I have refrained from giving wearisome details that are necessary for the investigator to observe carefully, but merely serve to confuse the reader, who desires to comprehend the broad principles only.

It is hoped and believed that these observations will throw light upon many obscure phenomena which have puzzled founders and others with respect to iron castings subjected to alternate heating and cooling, and that many practical applications of the observations here recorded will suggest themselves to others.

It has long been known that cast iron grate-bars, and other castings subjected to heat, warp, twist, buckle and crack, but these effects were attributed in some cases to the burning out of carbon, in others to the oxidation of iron, and also to absorption of sulphur from the fuel.

TABLE II. — *Results of Experimental Heatings of Cast Iron Test-Bar. Marked " C " No. 2, November 24, 1903.*

| | Number of Heats | Length | Expansion Since Last Measurement | Total Expansion | Rate of Exp'nsion Per Heat |
|---|---|---|---|---|---|
| | | Inches | Inches | Inches | Inches |
| 1st measurement . . | 10 | $12\frac{3}{16}$ | $\frac{3}{16}$ | $\frac{3}{16}$ | 0.019 |
| 2d measurement . . | 5 | $12\frac{1}{4}$ | $\frac{1}{16}$ | $\frac{1}{4}$ | 0.0125 |
| 3d measurement . . | 2 | $12\frac{3}{8}$ | $\frac{1}{8}$ | $\frac{3}{8}$ | 0.062 |
| 4th measurement . . | 11 | $12\frac{9}{16}$ | $\frac{3}{16}$ | $\frac{9}{16}$ | 0.017 |
| 5th measurement . . | 8 | $12\frac{11}{16}$ | $\frac{1}{8}$ | $\frac{11}{16}$ | 0.0156 |
| 6th measurement . . | 4 | $12\frac{7}{8}$ | $\frac{3}{16}$ | $\frac{7}{8}$ | 0.0156 |
| 7th measurement . . | 1 | $12\frac{15}{16}$ | $\frac{1}{16}$ | $\frac{15}{16}$ | 0.062 |
| 8th measurement . . | 8 | 13 | $\frac{1}{16}$ | 1 | 0.0077 |

NOTE.— This bar is a regular test-bar with chilled ends cut off, and measured exactly 12 in. long before treatment. Middle of the heat of November 24, 1903. Total expansion for 49 heats is 1 in. per foot, or at the rate of 0.0204 in. per heat.

In other cases, as in cast iron plates used in some glass-annealing ovens, these changes in form and the splitting or cracking of the plates were thought to be merely deformations caused by the temporary expansion of the plates while red-hot.

So far as my information and research goes, I believe it has not heretofore been known that cast iron actually increases in cubical dimensions to an extent not yet finally ascertained, but certainly exceeding 40 per cent above the original dimensions, without material change of composition or destruction of its metallic properties. It is also thought that the surprising difference in behavior of wrought iron and steel of all grades, when subjected to precisely similar treatment, will prove novel to many

TABLE III. — *Results of Experimental Heatings of Cast Iron Test-Bar. "E" No. 3, November 24, 1903.*

| | Number of Heats | Length | Expansion Since Last Measurement | Total Expansion | Rate of Exp'nsion Per Heat |
|---|---|---|---|---|---|
| | | Inches | Inches | Inches | Inches |
| Before heating | . . . | $14\frac{13}{16}$ | . . . . | . . . | . . . |
| 1st measurement | 10 | $14\frac{63}{64}$ | $\frac{11}{64}$ | $\frac{11}{64}$ | 0.0171 |
| 2d measurement | 5 | $15\frac{1}{16}$ | $\frac{5}{64}$ | $\frac{1}{4}$ | 0.0156 |
| 3d measurement | 2 | $15\frac{3}{32}$ | $\frac{1}{32}$ | $\frac{9}{32}$ | 0.0156 |
| 4th measurement | 11 | $15\frac{11}{32}$ | $\frac{1}{4}$ | $\frac{17}{32}$ | 0.0227 |
| 5th measurement | 8 | $15\frac{3}{8}$ | $\frac{1}{32}$ | $\frac{9}{16}$ | 0.0031 |
| 6th measurement | 4 | $15\frac{17}{32}$ | $\frac{5}{32}$ | $\frac{23}{32}$ | 0.039 |
| 7th measurement | 5 | $15\frac{5}{8}$ | $\frac{3}{32}$ | $\frac{13}{16}$ | 0.0187 |
| 8th measurement | 1 | $15\frac{3}{4}$ | $\frac{1}{8}$ | $\frac{15}{16}$ | 0.125 |
| 9th measurement | 4 | $15\frac{13}{16}$ | $\frac{1}{16}$ | 1 | 0.0155 |

NOTE.—This bar is one of the regular test-bars from the last of the heat of November 24, 1903, and measured $14\frac{3}{16}$ in. long when cast. It yielded a total expansion for 50 heats of 1 in. per 15 in., or at the rate of 0.02 in. per heat.

engineers and founders, one expanding greatly, the others contracting slightly under the heat treatment.

Dr. Charles B. Dudley has recently informed me that, within the past three years, some car-wheel makers have found that the re-annealing of car-wheels enabled them better to withstand, without cracking, the "thermal test" of the Pennsylvania Railroad Co., and have also noticed that such wheels measure as

TABLE IV. — *Results of Experimental Heatings of Steel Bars, Soft Steel, Tool Steel, Cast Steel and Iron.*

| Material | Original Length | No. of Heats | Contraction | No. of Additional Heats | Contraction | Total Heats | Total Contraction | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Per Foot | Per Heat |
| | Inches | | Inches | | Inch | | Inches | Inches |
| Soft steel bar, marked No. 2 | 12 | 40 | $\frac{6}{16}$ | 23 | $\frac{1}{16}$ | 63 | 0.125 | 0.002 |
| Tool-steel bar, marked No. 3 | 12 | 28 | . . | . . | . . | 28 | 0.023 | 0.0008 |
| Wrought iron bar, marked No. 4 | 12 | 28 | . . | . . | . . | 28 | 0.035 | 0.0012 |
| Piece of cast steel test-bar, tested for tensile strength | 9 | 10 | . . | . . | . . | 10 | $\frac{1}{32}$ in. per 9 in. | 0.0031 |

much as ⅜ in. larger in circumference than before the re-annealing. This is equivalent, on a 36-in. wheel, to ⅛ in. on 3 ft. diameter, or far less than the original shrinkage of the metal, and is infinitesimal as compared with the enormous increase in size of bars here shown, amounting, in one case, to over 40 per cent increase in volume. Moreover, a car-wheel is under very great compression strains due to the chilling of the rim, and it is natural to expect that it would tend to enlarge slightly owing to the more complete relieving of these compression strains by re-annealing. The wheels would, no doubt, continue to increase in size if re-annealed many times, as in the case of expanded bars.

It has also been suggested that the conversion of combined carbon into the graphitic form may have something to do with the enlargement of the castings. One answer to this — as already given — is, that white iron bars, in which practically all of the carbon is combined, do not expand, even after the breaking up of the whole of the combined carbon and its change into graphite, or, more correctly speaking, Ledebur's " temper " carbon (as in some modern malleableizing methods), sufficiently to overcome the original shrinkage of the metal. Furthermore, soft iron bars, having over two per cent silicon and very little combined carbon, expand much more under similar heat treatment than harder gray iron, containing much less silicon and much more combined carbon.

Dr. Dudley has also recently suggested that " absorption of oxygen " may possibly have some influence on these changes. In experiments which I made many years ago in casting iron in a mold faced with " carbonized fabrics," such as an embroidered lace veil, in which the carbon threads were as fine as cob-webs, I found that there was little or no tendency for the carbon to consume, showing that the oxygen of the air was driven off by the heat through the mold. It would seem, therefore, that in the first experiments in heating and expanding cast iron bars by pouring molten iron over them, there could have been no absorption of oxygen. In several of the more recent tests I have filled the iron tubes containing the bars to be expanded with charcoal, rammed tightly into the interstices between the bars in order to prevent oxidation, and found no appreciable difference in expansion from bars heated in a closed tube without charcoal. I have, however, contended for many

years (see lecture on cast iron in " Journal of the Franklin Institute," March, 1888) that iron melted in a cupola absorbs oxygen from the air-blast, and I have attributed the marked difference in quality between high chilling-iron melted in a cupola and the same iron melted in a reverberatory furnace largely to this cause. In my discussion on cast iron, printed in the " Journal of the Franklin Institute," November, 1900, the following sentence may be found: " Finally, I may say that I am convinced that the presence of iron oxide dissolved in the molten metal is a factor which is commonly overlooked, and is to be feared, especially in strong iron mixtures. The best deoxidizer with which I am familiar is ferro-manganese, a metal containing about 80 per cent manganese, which may be added either in the ladle or in the cupola, in the proportion of about 1 lb. to 600 lb. iron. The effect is to increase the strength and ductility, to decrease the chill, and to darken the gray color of the fracture in high-chilling iron mixtures. This discovery was first brought to the attention of metallurgists in an address above cited. Since that time the beneficial effects of ferro-manganese as a deoxidizer and de-sulphurizer in certain iron mixtures have become generally known, and its extensive use, especially in car-wheel foundries, has followed thereupon."

All of the investigations so far made in expanding cast iron by heat, whether by pouring molten iron over cold bars, heating in a closed tube with or without charcoal, heating in a fire without any protection, or by direct radiation of heat over a fire far removed from the flames (as in the protective grating shown in Fig. 5) producing practically the same results, tend to convince me that the astonishing change in volume is a molecular, not a chemical, one, thus substantiating my original theory of the molecular mobility of cast iron.

The peculiar property of cast iron of increasing in bulk under the influence of heat is inherent in the metal, and has existed in all time. It must, therefore, have been noticed to some extent long ago; but, so far as I am aware, no careful study has ever been made of the phenomenon, if it was observed, and no previous knowledge has, I believe, existed of the fact that a bar of iron can be increased in bulk more than 40 per cent over the original volume while in the solid condition and still retaining its metallic properties. The decrease in strength appears

to bear a certain relation to the degree of expansion of the test-bars. In conclusion, I wish to repeat what I said in my first communication in 1896, viz.: "My paper, therefore, is not presented as an exhaustive, but as a tentative, treatment of this interesting and, I believe, novel line of research, which is not incapable, even in its present stage, of some practical applications." I desire, furthermore, to repeat that I consider that these investigations afford corroborative proof of the correctness of the theory of "the mobility of molecules of cast iron," advanced to explain the phenomena noted in my paper of February, 1896. I also wish to say that I am indebted to Mr. William H. Maw, Editor of "Engineering" (London), for some valuable suggestions communicated during the past six months.

## CHEMICAL SPECIFICATIONS FOR PIG IRON*

By EDGAR S. COOK
Pottstown, Pennsylvania

PORTIONS of this paper repeat in substance the statements made by me in an address before the meeting of the American Society for Testing Materials, held in June, 1903, at Delaware Water Gap, Pa. The views I then expressed I still hold, and believe to be pertinent to the present discussion of this subject. In doing my part, therefore, at the request of our Secretary, towards the further consideration by the Institute of the Physics of Cast Iron from a commercial as well as a theoretical standpoint, — a theme which received interesting treatment in our meeting some years ago, but has been somewhat neglected recently, — I make no apology for reiterating the views I have expressed elsewhere.

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*Atlantic City Meeting of the American Institute of Mining Engineers.

Indications all point to the substitution of classifying pig iron by chemical analysis for the old-time method of grading by fracture. Commencing with the larger users, and the makers of specialties, who require more positive information as to the composition than is afforded by the fracture, the use of pig iron, guided by analysis, has spread with much greater rapidity to all classes of foundry-work than the most sanguine expected.

Grading by fracture, as guided by experience with any particular brand of iron, has some points in its favor. The fact that for so many years castings of multitudinous forms, and for an endless variety of uses, were made in a fairly satisfactory manner by skilful guessing as to mixtures, shows that, for many classes of work, a considerable range in composition may be allowed, without injuriously affecting the castings. But with accurate knowledge as to requirements, and more positive information as to the composition of pig iron, there will doubtless be a smaller percentage of defective castings.

Working by analysis, however, will not prove a panacea for all the ills of foundry practice. There are many causes affecting the success of such practice other than the composition of the iron charged into the cupola.

There are limitations, also, to the ability of the blast-furnace to furnish pig iron according to rigid chemical specifications without unduly enhancing the cost. In the long run the consumer must pay the cost and risks of manufacture, plus a fair profit on the capital invested; otherwise the supply will not equal the demand.

The manufacture of special irons having a certain composition, with very narrow limits of permissible variation, demands special ores and special fuels, as well as uniform conditions of furnace-work. Such ores and fuels are not in abundant supply, and therefore command comparatively high prices; while the unavoidable "misfits" made by the furnace, and sold at less than cost, enhance the average cost of manufacture, for all of which the consumer must ultimately pay.

Blast-furnaces could be run with much more comfort to the manager, and with much better average results in every way, if it were possible to obtain absolutely uniform raw material, and if the atmospheric air driven into the tuyères always contained the same weight of oxygen and of moisture per cubic foot. But if all

the furnaces operating to-day were forced to demand ores of uniform composition, always the same in percentage of iron and gangue, and coke that did not vary in sulphur, phosphorus, ash and fixed carbon, most of them would be obliged to blow out; and the cost of pig iron would rise to prohibitory figures.

The furnaces are obliged, therefore, to take raw materials as they find them, and, by judicious mixing, based upon an *approximate* knowledge of their contents, make as uniform a product as possible.

This product is the raw material of the foundry, rolling-mill, steel-works, etc. It is a wise precaution, therefore, in substituting grading " by analysis " for grading " by fracture," not to draw the lines closer, nor make the conditions more severe than is absolutely necessary to meet the requirements of the particular class of manufacture concerned.

I have seen crude specifications for pig iron, probably formulated by a young chemist, fresh from school, but without metallurgical practice, which were so pedantically exacting with regard to carbon, silicon, sulphur, phosphorus, manganese, etc., that probably not one cast in a thousand from any one furnace would meet all conditions imposed. Such specifications indicate ignorance of the inevitable variations in the composition of pig iron, especially of sand-cast pig, made in the usual way. Different portions of the same pig, different beds of the same cast, even different pigs of the same cast, frequently show considerable variations in sulphur and silicon. Without attempting here to discuss the causes of such variations, we must accept the fact as an unavoidable feature of the conditions, and existing at most blast-furnaces.

In this connection I cannot do better than quote the remarks of Dr. R. W. Raymond, in a discussion upon " The Control of Silicon in Pig Iron."*

" This apparatus [the blast-furnace] is noted as perhaps at once the rudest and the most sensitive of the means employed in manufacturing on a large scale. In proportion to its rudeness and sensitiveness, it has always called for exceptional skill in management. By skill, I mean here the acquired aptitude of actual practice, including the recognition of symptoms, without the perfect knowledge of their causes. The requirement of skill in this sense has been greatly diminished by the work of chemist and

* "Transactions," xxi., 361, February, 1892.

engineers during the last few years. Many of the subtle difficulties and
traditional remedies of the blast-furnace practice of twenty years ago
are practically obsolete in the art of to-day, with its rapid running, high
pressures and temperatures, immense daily products and adequate ma-
chinery. But the hampering condition still remains, that these great fur-
naces, devouring hundreds of tons of raw material, and producing hun-
dreds of tons of pig iron and slag daily, are required to preserve a certain
chemical composition of product. This requirement is often inconsistent
with the use of the cheapest ores, the maximum economy of fuel and the
maximum product of iron. In other words, if our blast-furnace managers
were ordered to produce the largest practicable quantity of pig iron, no
matter of what grade or quality, at the smallest cost of ore, flux, fuel,
labor and repairs, the art would be not only simplified, but revolutionized.

"Now this is what has happened in other arts, as the result of
scientific improvement. The production of the cruder material has been
immensely cheapened, by reducing the element of skill, removing to a
great extent the requirement of complicated quality, and leaving to sub-
sequent processes, in which science, rather than skill, plays the chief part,
the final work of perfection and adaptation.

"The barbaric method (as illustrated, for instance, in the Japanese
manufacture of steel) consists in the infinite expenditure, according to
received tradition, of material, time and labor; the rejection of the greater
part of the product; and the selection of that part which by happy accident
has acquired extraordinary excellence.

"The half-civilized method substitutes more and more skill for luck,
and science for skill, yet still waits to see what the product will be, and
'grades' it, without reference to what it was intended to be.

"The scientific method makes what it started to make. To do this,
it requires to know and to govern all the conditions of manufacture, in-
cluding the exact composition of materials. If this knowledge and control
cannot be easily maintained in the first step of manufacture, or if their
exercise interferes with the economical operation of that stage on a
large scale, the scientific method employs that part of its process as a
means of simplifying the conditions for future determination and control."

Blast-furnace practice may be said to be in the "half-civil-
ized" state, we blast-furnace managers having preceded our
foundry friends in emerging from the "barbaric" stage by
nearly a score of years. But the foundry is really most inter-
ested in knowing the exact composition of its raw material —
pig iron. This is more important than having it rigidly con-
form to any particular set of specifications, defining the limits
of silicon, sulphur, etc. It is for the foundry manager, knowing
the composition of his raw material, to employ the scientific
method, and, if unable to obtain one pig iron meeting all his

requirements, to make such a mixture of various irons as will produce the result he seeks.

The correct sampling of sand-cast pig, especially of the foundry grades, is troublesome and expensive. For a fairly representative sample, numerous pigs must be drilled with care. Even then, different samplings of the same lot of iron will show frequently, under the same method of analysis, widely varying results as to silicon and sulphur. This occasions misunderstandings, quite as difficult to adjust as disagreements with respect to the " fracture " indicating any particular " grade."

I do not refer only to controversies affecting the price, where judgment may be warped by money-considerations. I have in mind several experiences of our own, illustrating the difficulty of arriving at the composition of sand-cast pig, when the question of price did not enter into the matter at all, as no particular guarantees had been made. The purchaser required reasonably accurate information to guide him in using the iron; and we coöperated with him in sampling and making analyses. All the samples were made by drilling about one dozen pigs to represent each lot of 50 tons. The comparative results were as follows:

TABLE I. — *Comparative Analyses of Samples of Pig Iron, Taken by Drilling of Sand-Cast Pigs.*

PURCHASERS, WARWICK IRON AND STEEL CO.

| Silicon | Sulphur | Silicon | Sulphur |
|---------|---------|---------|---------|
| Per Cent | Per Cent | Per Cent | Per Cent |
| 1.90 | trace | 0.964 | 0.045 |
| 1.23 | 0.04 | 0.926 | 0.045 |
| 0.85 | 0.09 | 0.855 | 0.050 |
| 1.71 | 0.035 | 0.880 | 0.040 |
| 1.08 | 0.040 | 0.910 | 0.060 |
| 1.03 | 0.06 | 1.010 | 0.080 |
| 1.04 | 0.05 | 1.08 | 0.050 |
| 1.31 | 0.04 | 1.19 | 0.04 |
| 1.50 | 0.03 | 1.09 | 0.06 |
| 0.62 | 0.05 | 0.74 | 0.04 |
| 0.87 | 0.03 | 0.80 | 0.04 |
| 1.21 | 0.04 | 0.92 | 0.07 |
| 1.04 | 0.05 | 1.08 | 0.05 |

The marked discrepancies in silicon were found to be due to particles of sand included in the samples, through lack of care in the drilling of the sand-coated pigs in the machine-shop of the purchaser. The iron sold was all "gray forge."

This experience led us to adopt the method of sampling iron liquid, as it ran from the furnace, which was in the use by the western furnaces connected with steel works. It has been found more reliable, as fairly representing iron to be used in quantity, than the drilling of individual pigs.

Sometimes, consecutive casts of pig iron prove to be remarkably uniform as to silicon and sulphur, the differences between the different beds not exceeding the permissible laboratory-variation; but this is the exception rather than the rule. Phos-

TABLE II. — *Analyses of Drillings from Pigs of the Same Cast.*

| Beds | Open Gray Forge A | | No. 2 Strong B | | Soft Foundry C | | D | |
|---|---|---|---|---|---|---|---|---|
| | Silicon | Sulphur | Silicon | Sulphur | Silicon | Sulphur | Silicon | Sulphur |
| | Per Cent | Per Cent | Per Cent | Per Cent | Per Cent | Per Cent | Per Cent | Per Cent |
| 2...... | 1.481 | 0.068 | 1.669 | 0.013 | 2.52 | 0.011 | 2.52 | 0.014 |
| 4...... | 1.434 | 0.066 | 1.575 | 0.009 | 2.60 | 0.015 | 2.56 | 0.013 |
| 6...... | 1.468 | 0.074 | 1.599 | 0.009 | 2.66 | 0.013 | 2.58 | 0.013 |
| 8...... | 1.481 | 0.066 | 1.599 | 0.003 | 2.80 | 0.013 | 2.53 | 0.012 |
| 10...... | 1.458 | 0.056 | 1.622 | 0.009 | 2.92 | 0.013 | 2.55 | 0.012 |
| 12...... | 1.411 | 0.060 | 1.575 | 0.011 | 3.01 | 0.011 | 2.56 | 0.013 |
| 14...... | 1.292 | 0.066 | 1.528 | 0.011 | 2.92 | 0.011 | 2.48 | 0.013 |
| 16...... | 1.198 | 0.056 | 1.528 | 0.006 | 2.04 | 0.014 | 2.84 | 0.013 |
| 18...... | 1.222 | 0.055 | 1.411 | 0.011 | ........ | ........ | ........ | ........ |
| 20...... | 1.222 | 0.048 | 1.363 | 0.008 | ........ | ........ | ........ | ........ |

CAST ANALYSIS, LIQUID SAMPLES

| ........ | 1.363 | 0.054 | 1.599 | 0.012 | 2.60 | 0.011 | 2.50 | 0.013 |
| ........ | ........ | ........ | ........ | ........ | 2.23 | 0.013 | 2.88 | 0.015 |

Cast A. — The silicon varies between 1.481 and 1.222 per cent, and the sulphur between 0.074 and 0.048 per cent.

Cast B. — The silicon varies between 1.669 and 1.363 per cent, while the sulphur happens to be exceptionally low.

Cast C. — Shows a wide variation in silicon from 3.01 to 2.04 per cent, while the sulphur is low and constant.

Cast D. — Represents a cast uniform in both silicon and sulphur.

phorus is generally evenly distributed. Segregation does not seem to affect it, and there is seldom difficulty in determining it. Table II, on page 387, illustrates the variation of silicon and sulphur in sand-cast iron, one pig being selected from the middle of every alternate bed.

Another series might be still more variable in silicon and sulphur, according to furnace conditions.

Table III gives the analyses of drillings from different portions of the same cast of sand-cast pig.

TABLE III. — *Analyses of Drillings from Pigs Taken at Random from the Same Cast.*

| Grade | First Sample | | Second Sample | |
|---|---|---|---|---|
| | Silicon | Sulphur | Silicon | Sulphur |
| | Per Cent | Per Cent | Per Cent. | Per Cent |
| No. 2X . . . . . . . . | 2.23 | 0.017 | 2.45 | 0.015 |
| No. 2X . . . . . . . . | 3.29 | 0.014 | 2.30 | 0.091 |
| No. 2X . . . . . . . . | 2.16 | 0.022 | 1.46 | 0.018 |
| No. 2X . . . . . . . . | 2.15 | 0.036 | 2.40 | 0.027 |
| No. 2X . . . . . . . . | 3.24 | 0.035 | 2.16 | 0.060 |
| No. 2X . . . . . . . . | 3.20 | 0.026 | 3.32 | 0.017 |
| No. 2X . . . . . . . . | 3.21 | 0.051 | 3.17 | 0.036 |
| No. 2. . . . . . . . . . | 1.62 | 0.075 | 2.58 | 0.033 |
| No. 2. . . . . . . . . . | 1.88 | 0.035 | 2.66 | 0.013 |
| No. 3 . . . . . . . . . | 1.25 | 0.035 | 0.89 | 0.050 |

Table IV gives another example.

Where the iron represented by one analysis ends and the other begins, it is difficult to determine. Occasionally, physical indications serve as a guide to the experienced grader.

These illustrations show the difficulties besetting the accurate determination of the composition of sand-cast pig. When the situation is complicated by commercial considerations, it is evident that grading by analysis may not remove all friction of interests, though it is unquestionably an improvement upon grading by fracture, and certainly a safer guide as to the use of pig iron. Fortunately, for most classes of foundry-work, moderate variations in the composition in carefully-selected

TABLE IV. — *Analyses of Liquid and Solid Samples from the Same Cast.*

| LIQUID SAMPLES | | | |
|---|---|---|---|
| | Silicon Per Cent | Sulphur Per Cent | |
| | 2.20 | 0.021 | |
| | 2.85 | 0.017 | |

| Drillings | | | Drillings | | |
|---|---|---|---|---|---|
| Bed. No. | Silicon | Sulphur | Bed. No. | Silicon | Sulphur |
| | Per Cent | Per Cent | | Per Cent | Per Cent |
| 1.............. | 1.99 | 0.026 | 11............ | 2.60 | 0.023 |
| | | 0.022 | 13............ | 2.66 | 0.022 |
| 3............. | 2.17 | 0.022 | 15. ........ .. | 2.85 | 0.020 |
| 5............. | 2.29 | 0.024 | 17............ | 2.36 | 0.019 |
| 7............. | 2.46 | 0.024 | 19 ........... | 1.80 | 0.021 |
| 9............. | 2.57 | 0.027 | | | 0.024 |

This cast shows considerable variation in silicon, while the sulphur is uniform.

foundry-irons are not fatal, because a certain range in chemical composition has been found permissible in practice.

At the Delaware Water Gap meeting of the American Society for Testing Materials, the Sub-Committee on Pig Iron presented a report on the classification of pig iron, which, after prolonged discussion, was provisionally modified by the action of that meeting. In its modified form, the report was subsequently submitted by letter to the members of the Pig Iron Sub-Committee, approved by them, and then transmitted to the Secretary of the Society, for further action by the members thereof. It is not necessary for me to discuss in detail all the differences between it and the original report of the sub-committee. One of them, however, is worthy of notice, as throwing some light upon the problem involved and the spirit in which it has been approached. Namely, the sub-committee originally suggested the provision that " in the absence of specifications " the current grades of pig iron should be considered as representing the following chemical composition:

| Grade | | | | | Silicon Per Cent | Sulphur Per Cent |
|---|---|---|---|---|---|---|
| "Scotch," | . | . | . | . | Over 3.0 | Not over 0.03 |
| "No. 1," | . | . | . | . | 2.5  to 3.0 | Not over 0.03 |
| "No. 2X," | . | . | . | . | 2.0  to 2.5 | Not over 0.045 |
| "No. 2," | . | . | . | . | 1.75 to 2.25 | Not over 0.055 |
| "No. 3," | . | . | . | . | 1.50 and over | Not over 0.075 |

The modified report omits the grades known as "Scotch" and "No. 2X," and substitutes the following classification:

| Grade | | | | | | | | Silicon Per Cent | Sulphur Per Cent |
|---|---|---|---|---|---|---|---|---|---|
| "No. 1," | . | . | . | . | . | . | . | 2.75 | 0.035 |
| "No. 2," | . | . | . | . | . | . | . | 2.25 | 0.045 |
| "No. 3," | . | . | . | . | . | . | . | 1.75 | 0.055 |
| "No. 4," | . | . | . | . | . | . | . | 1.25 | 0.065 |

with a permissible variation of 0.01 per cent of sulphur and 10 per cent of the quantity of silicon. It will be understood that these figures are offered simply as a means of characterizing "grades" of iron, when no chemical specification has been made. Of course, an intelligent and reasonable chemical specification would supersede this provisional classification.

## DISCUSSION *

*R. W. Raymond, New York City:* The extracts presented in Mr. Cook's paper from the remarks on this subject made by me a dozen years ago, represent my views at the present day so fully that I do not care to modify them. But I would emphasize in addition, a principle involved, not only in Mr. Cook's paper, but also in many of the opinions of other experts expressed in to-day's discussion and also in previous discussions of this subject, and of others cognate to it. It is really, in my judgment, the main principle which underlies the relation between makers and users, with regard to specifications, and therefore I think it deserves to be clearly stated by itself. This principle is, *that rigorous specifications, inevitably involving and inviting lax inspection, should be avoided, and that specification should be made as liberal and lenient as is practically consistent with the purpose in view, and then enforced by an absolutely rigorous inspection.*

In too many cases, contrary method has been followed. Demands have been made of the manufacturer which he could not

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* This discussion is subject to revision.

fully satisfy. In one instance of this kind, known to me, a government board of experts set up for certain manufactures of steel, specifications combining the extremes of all the chemical and physical requirements contained in all the existing specifications which they could find, not realizing that the fulfillment of one such requirement would practically prevent the fulfillment of another. The result of such pedantic specifications is a twofold mischief. In the first place, prudent manufacturers will not undertake to satisfy them; and, in the second place, adventurous or unscrupulous parties will take the job, either because they do not appreciate its difficulty, or because they expect to hoodwink the inspector, or because they rely upon some illegitimate influence to pull them through, and get them paid, in spite of the absurd conditions which they have failed to satisfy. This is, in fact, an old trick of corrupt officials, by means of which honest competitors are discouraged. I remember characterizing it, many years ago, in an article in the " Engineering and Mining Journal " under the title " Bulldozing Contractors." But it is not by any means only corrupt officials who are guilty of it. Scientific zeal may lead honorable experts to commit the same mistake. And the cure for the resultant difficulties and mischiefs is, I think, to be found in minimum requirements of specifications and then (but only then) rigorous enforcement thereof. In other words, let the contract cover the widest permissible variation, but give the inspector no discretionary power to enlarge these.

It is of the utmost importance that, in carrying a reform as is now proposed, and indeed, required by the progress of modern practice, we shall secure the means of knowing that we get from the maker the thing we have called for: and the only way to do this is to call for no more than we really want and he can practically furnish.

*James Gayley, New York City:* The main thing that is sought after in this matter is that all purchases shall be made by analysis. This is done already in special lines, as in the manufacture of various grades of steel in which phosphorus, silicon and sulphur are specified within their narrow limits, and I quite agree with Mr. Cook that specifications which are over rigid in unessential particulars should be avoided, as they defeat their own purpose because unreasonable requirements permitting no variation are practically not fulfilled, and it is impossible to specify grade

and analysis in an apparatus so variable in its results as a blast-furnace.

What is desired for the consumer is an honest grade of iron, and that is obtainable far easier through stipulation as to analysis than as to grade. I do not quite understand according to the specifications of the several grades of iron why the committee has only specified silicon and sulphur, while the phosphorus, which has such an important influence in foundry operations, should have been omitted. The different makers produce a brand of iron which contains phosphorus varying within certain limits, but it becomes necessary for the consumer to be acquainted with the character of the brands that are on the market with respect to their content in phosphorus. It seems to me that it would be far better to stipulate by some brand name an iron containing a certain percentage of phosphorus, as for instance, an iron containing 0.25 to 0.50 phosphorus be designated say as *Alpha* grade; for 0.50 to 0.75, *Beta* grade; 0.75 to 1 per cent *Gamma* grade, and 1 to 1.25 per cent *Delta* grade, etc., so that a consumer ordering iron can specify No. 1 or No. 3 *Alpha* or *Delta* grade, as will suit his requirements, and, irrespective of the furnace company from which he purchases, is assured of obtaining an iron that is practically uniform as respects silicon, sulphur and phosphorus.

This system of grading is in use at the mines controlled by the Steel Corporation in the Lake Superior region, in which the name of the grade of ore beginning with A represents the best Bessemer grade, the word beginning with B represents non-Bessemer grade, and the one beginning with C represents a lower grade of ore than either of the other two; as for instance, at the Mansfield Mine, the various grades are designated as Atfield, Barfield, Clearfield, and at the Buffalo Mines the grades are Alamo, Buffalo, Cameo, the termination of the word being used to designate the mine in addition. This suggests to me that something on a similar basis might be used to advantage in the grading of foundry iron.

Another point has been brought out in a discussion of iron for foundry purposes and that is that much trouble may arise from the content of oxygen. It occurs to me that much valuable time is lost in looking for some unusual content in pig iron, to which great and mysterious influences are attached, whereas the conditions under which iron is remelted, the content of sulphur in the coke, and the amount of scrap that is mixed with the

iron, about which generally the founder knows little or nothing, exert a far greater influence.

I recall an experience I had when connected with the Carnegie Steel Company, in endeavoring to find out the superiority of charcoal iron for the making of car-wheels. A certain grade of charcoal iron which contained about 0.75 phosphorus had given excellent results in the making of car-wheels, and inasmuch as we had on hand a stock of ore at one of our furnaces exceedingly low in phosphorus we concluded to make some iron on a very low temperature of blast that would contain about 0.03 phosphorus. This iron we made with a hot blast temperature of 300° F., as against the charcoal iron with 500 degrees. The resultant metal contained approximately, as I recollect, the same percentage of silicon and carbon as the charcoal metal, but it did not yield the same results in the manufacture of car-wheels.

Before making this experiment I had consulted with Mr. Wm. Metcalf of Pittsburg, who has long been known as a very careful investigator in iron and steel metallurgy, as to the superiority of charcoal iron, and he had suggested that it was perhaps due to the absorption of nitrogen, that he had found a very great variation in content of nitrogen in various steel, and that the charcoal iron with a cold blast would absorb less nitrogen than iron made with a hot blast, irrespective of whether the fuel was charcoal or anthracite. In order to test this the low phosphorus iron was manufactured with a blast temperature of 300 degrees. Samples of this low phosphorus iron and the charcoal iron, and of our standard Bessemer iron and a piece of basic iron taken indiscriminately from a pile containing about 0.50 phosphorus, were sent to Prof. Langley for determination of nitrogen. We looked forward with keen interest to the returns from these samples, expecting that the low phosphorus and the charcoal iron would show so much better, but instead the basic iron, from which we expected nothing, was materially lower in content of nitrogen, and was made perhaps with the highest temperature of hot blast. Since that time I have regarded with more or less indifference the claims that are put forward respecting the great influence that is exerted by the gaseous content in pig iron. Both the steel maker and the foundrymen will obtain far better results when pig iron can be made with far more uniformity than is possible under present conditions. In a furnace using Lake Superior ores it requires approximately 7,200 pounds of raw material and

11,700 pounds of air to produce a ton of iron. The raw material is controlled now within a variation of 10 per cent, whereas the air will vary in a single day as much as 100 per cent. Experiments are now under way which will demonstrate during the current year what increase in uniformity can be obtained in the blast-furnace, by making the air consumed per ton of pig iron as uniform as the raw material.

*James P. Roe* (Communication to the Secretary)

Although Mr. Cook's paper refers chiefly to specifications of pig iron for use in foundry work, a passing word on the use of machine-cast pig iron and the knowledge of its chemical composition for mill use may not be out of place.

Broadly, the greater number of constants that can be introduced into a given operation the more uniform will be the result. Therefore, given an iron containing a known and uniform amount of the various metalloids, it is possible to obtain a product of relative uniformity, and, what is of the greatest importance, a basis for the associated ideas of cause and effect.

As an illustration of the extreme crudity of grading by fracture, the following analyses are submitted of sand-cast pig irons shipped by the blast-furnaces as gray-forge irons, and mottled irons, respectively, and similarly graded by fracture by our chemist. The analyses from these irons showed:

| Gray-forge | | Mottled | |
|---|---|---|---|
| Sulphur Per Cent | Silicon Per Cent | Sulphur Per Cent | Silicon Per Cent |
| 0.035 | 2.06 | 0.166 | 2.00 |
| 0.140 | 0.65 | 0.236 | 2.40 |
| 0.016 | 0.61 | 0.057 | 0.24 |

These extreme variations are by no means as uncommon as might be supposed, and they are representative, although in less degree, of sand-cast pig iron in general. Such variations explain the wisdom of the common practice in puddling of mixing a number of brands of pig iron together, the probability being that only one brand would get " off " along certain lines at a given time, and that this would be neutralized wholly or in part by the others.

The advantages of machine-cast pig iron for mill purposes are: (1) greater fusibility of a given grade, due to the absence of the relatively infusible coating of silica; (2) reduced loss, due to the same cause; and (3) relatively uniform chemical composition.

I wish to emphasize the importance of uniformity in chem-

ical composition. The analysis of a pig that is representative of a shipment is of value, while the analysis of a pig that is not representative is valueless. A sand-cast pig is less likely to be representative than a machine-cast pig. Another feature worthy of note is that an exact knowledge of the chemical composition of a pig iron is of more value than a too narrow limitation of the individual components. This statement is fully proved by the relatively high phosphorus and sulphur of certain brands of celebrated finished irons. In closing, I beg to call attention to an argument frequently made that because the presence of the same metalloids in large quantities is disastrous, the presence of the same metalloids in small quantities is proportionally disastrous. This deduction is not true, for the reason that the presence of a small proportion of certain metalloids is often of positive good to the iron.

## SPECIFICATIONS FOR PIG IRON AND IRON CASTINGS*

By ROBERT JOB
Reading, Pennsylvania

U P to five years ago the pig iron used by the Philadelphia & Reading Railway Co. had been obtained solely upon the appearance of the fracture, but as the service was unsatisfactory, an investigation was made to determine the quality best adapted to the requirements of the company. It was found in the first place that the proportions of phosphorus and of silicon were high, which resulted in the castings having a rather low tensile strength and being weak under impact. After a study of the quality and conditions of the scrap of the company, as well as of the service desired, specifications were

drawn up substantially in the form of those herewith appended, limiting the proportion of phosphorus to 0.5 per cent, and the proportion of silicon to about 1.5 per cent, holding the latter component in practice to about 1.75 per cent also, as some of the scrap was rather high in sulphur, a minimum of 0.4 per cent was placed on the manganese-content of the pig iron, and ferromanganese was used in the ladle. The result of these changes was to produce a tough, close-grained, easily-machined casting of high resistance under impact.

By the end of the first year after beginning to use this iron, the breakages had decreased to such an extent that the company's supply of scrap was largely cut off, and by the end of the second year the supply had decreased to so low a point that it became necessary to get the scrap for the cupola-furnaces elsewhere, and to purify it by an additional treatment.

## Specifications for Iron Castings (Philadelphia & Reading Railway Co.*)

I. *Physical Requirements.*— All castings must be of uniform quality, and of solid iron free from physical defects and excessive shrinkage strains, finished in a workmanlike manner, free from sand, and in close accordance with drawings. Castings purchased under Class 1 or Class 2 must be of gray iron throughout and easily machined.

II. *Chemical Requirements. — Class 1. Medium Iron —* Engine cylinders, gears, wheel centers, smoke stack, etc. The iron must be close grained and tough. The composition must be silicon, from 1.4 to 2; sulphur, not exceeding 0.085; manganese, not exceeding 0.7; phosphorus, not exceeding 0.6 per cent.

*Class 2. Soft Iron. —* Small castings for general car and roadway use. The composition must be silicon, from 2 to 2.8; sulphur, not exceeding 0.085; manganese, not exceeding 0.7; phosphorus, not exceeding 0.6 per cent.

*Class 3. —* Brake-shoes and other castings for frictional wear. The iron must be hard and tough. The composition must be silicon, from 2 to 2.5; sulphur, not exceeding 0.15; manganese, not exceeding 0.7; phosphorus, not exceeding 0.7 per cent.

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*Office of First Vice-President, Philadelphia, Pa., February 24, 1903, Theodore Voorhees, First Vice-President.

III. *Method of Inspection.* — Upon receipt of a shipment, a thorough inspection will be made, and only those castings will be considered which meet the requirements of Section 1. From such castings borings will be taken from at least one in each fifty or fraction thereof, and the composition must be within the stated limits or the shipment will be rejected.

IV. *Rejected Material.* — All rejected material will be returned at the expense of the shipper, and all castings which fail in service owing to defects of manufacture must be replaced free of cost.

## Specifications for Pig Iron (Superseding Previous Specifications) (Philadelphia & Reading Railway Co.*)

I. *Physical Requirements.* — Shipments must be of uniform quality, and free from sand, dirt, slag, or other foreign matter. Pigs must be broken, or be of such size as to be easily handled.

II. *Method of Sampling.* — Upon inspection, three pigs will be selected at random from each carload or fraction thereof, and a sample of drillings obtained by boring into the face of a fractured end of each of the three with a blunt, wide-angled two inch drill, to a depth of not less than two inches, care being taken to have the drillings uniformly fine and free from sand or other foreign matter. The samples from these three pigs will then be thoroughly mixed, and this final sample upon analysis must conform to the following composition, or the carload represented will be rejected.

III. *Chemical Composition.* — The chemical composition must be silicon, from 1.5 to 2.5; manganese, from 0.4 to 0.75; phosphorus, not exceeding 0.50; sulphur, not exceeding 0.04 per cent.

IV. *Rejection.* — In case of rejection at the shops, the material will be returned at the expense of the shipper.

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* Office of First Vice-President, Philadelphia, Pa., February 24, 1903, Theodore Voorhees, First Vice-President.

# THE STANDARDIZATION OF SPECIFICATIONS FOR IRON AND STEEL. RECENT PROGRESS IN AMERICA AND ENGLAND*

By WILLIAM R. WEBSTER and EDGAR MARBURG
Philadelphia, Pennsylvania.

THE desirability of bringing about greater uniformity in specifications governing iron and steel is generally recognized,



Edgar V. Marburg.

and has found expression within recent years in the efforts of numerous technical societies in that direction.

When the International Association for Testing Materials was organized at Zurich in 1895, a committee was appointed, charged as follows:

" On the basis of existing specifications, to seek methods and means for the introduction of international specifications for testing and inspecting iron and steel of all kinds."

The American representation on this international committee consisted originally of five and now of eight members. In view of the magnitude and importance of the subject, the Executive Committee of the American Section of the International Association for Testing Materials, since incorporated as the American Society for Testing Materials, appointed a committee of 34 members, including the American members of the above-named international committee, to frame standard American specifications for iron and steel. This committee reported on specifications for (1) Structural Steel for Bridges and Ships; (2) Structural Steel for Buildings; (3) Open-Hearth Boiler-Plate and Rivet-Steel; (4) Steel Rails; (5) Steel Splice-Bars; (6) Steel Axles; (7) Steel

*Atlantic City Meeting of the American Institute of Mining Engineers, February, 1904.

Tires; (8) Steel Forgings; (9) Steel Castings; (10) Wrought Iron.

These specifications were designed to be fairly representative of the best current American practice, and were adopted by letter-ballot of the Society in August, 1901.

The leading engineering societies have participated at various times in the discussion of these specifications and have lent valuable assistance through the appointment of special committees on like or closely related subjects.

The American Society of Civil Engineers discussed the specifications for Structural Steel for Bridges and Ships, and appointed a Committee on Steel Rails to report on Sections, Methods of Manufacture, Specifications, and Methods of Testing and Inspection.

The American Society of Mechanical Engineers discussed the specifications for Boiler-Plate and Rivet-Steel, Steel Forgings, and Steel Castings, and a committee of that society presented last year a report on these specifications, subject to revision, recommending certain modifications.

The American Master Mechanics' Association appointed a committee to report on the specifications for Steel Axles and Steel Forgings. This committee made a preliminary report last year, and has the matter still under consideration.

The American Railway Engineering and Maintenance of Way Association appointed separate committees to report on specifications for Bridge Materials and Steel Rails. These specifications, which differ somewhat from those of the American Society for Testing Materials, were adopted by vote of the Association, the former in 1903 and the latter in 1902. The Committee on Steel Rails has been instructed, however, to consider certain proposed modifications.

The American Institute of Mining Engineers has coöperated in this work by discussing the specifications for Steel Rails, Steel Forgings and Steel Castings, and is now asked to assist again by including in the discussion on the "Physics of Cast Iron" the specifications proposed by the Committee on "Standard Specifications for Cast Iron and Finished Castings" of the American Society for Testing Materials. These specifications, which will be presented at this meeting by the Chairman of the Sub-Committees concerned, comprise (1) Specifications and Grading of Pig Iron;

(2) Cast Iron Water- and Gas-Pipe; (3) Cylinder-Castings; (4) Car-Wheels; (5) Malleable Iron; (6) General Castings and Methods of Testing.

The above presentation covers in brief outline the recent history of the movement on the part of technical societies in this country in the direction of the standardization of specifications for iron and steel. The desirability of arriving at some uniform basis of reasonableness in specifications governing iron and steel products is too obvious for extended argument. The ordering of material which is to be subjected to similar or identical conditions of service under a great multiplicity of specifications, differing often more in the letter than in the spirit, is harassing to the manufacturer and of no real advantage to the consumer. The latter should recognize that any unnecessary burden imposed on the manufacturer must necessarily react in the end upon the consumer, and increase the average cost of the product without attendant gain in average quality. On the other hand, the manufacturer should recognize his obligation to spare no reasonable effort or expense to ensure a high-grade product of uniform quality, and should evince a willingness to provide adequate facilities for testing.

The existing differences between the leading specifications framed within recent years are in the main on matters of minor importance, and what has been done has resulted in a considerable clearing of the atmosphere. That further efforts will be put forth to reconcile the remaining differences as far as possible cannot be doubted. If the task be approached in a fair and open spirit of compromise between interests whose divergence, broadly viewed, is more apparent than real, all parties will be the gainers. If this work be promptly initiated, it is not too much to hope that American standard specifications approved by the leading technical societies, and covering the principal iron and steel products, will be available for presentation at the Seventh Session of the International Railway Congress to be convened in Washington, D. C., in May, 1905, and that they will prove an important step towards the ultimate realization of international standard specifications.

Turning now to a brief review of the present situation in England, it will be seen that much the same agencies have been set at work there, and that the outlook is in some respects even more auspicious than in America.

The movement in England had its origin in the appointment by the Institution of Civil Engineers of a Committee on Engineering Standards, which began its labors in 1901. The Institution of Civil Engineers secured the coöperation of the Institution of Mechanical Engineers, the Institution of Naval Architects, the Iron and Steel Institute and the Institution of Electrical Engineers, and the appointment by these several societies of representatives on the committee. According to a recently published announcement these " five leading technical institutions are thus actively and financially supporting and controlling the operations of this important movement."

In recognition of the great national importance of this undertaking, the British Government has lately authorized a grant of £3,000 towards the necessary expenses, and the India Government has agreed to contribute an additional sum of £1,000.

The War Office and Admiralty Departments, who are among the largest users of iron and steel, are actively coöperating in this work, and there are now more than 24 representatives of the Government on the various Sub-Committees. Representation on these Committees has also been accorded to numerous engineering, scientific and trade organizations, to the International Association for Testing Materials, as well as to the leading manufacturing and consuming interests.

The scope of the field which this Committee on Engineering Standards proposes to cover may be judged from the following list of Committees and Sub-Committees:

1. Sections used in Ship Building (11 members).
   (a) Sub-Committee on Tests for Iron and Steel Material Used in the Construction of Ships and their Machinery (23 members).

2. Bridges and General Building Construction (12 members).

3. Railway Rolling-Stock Underframes (13 members).

4. Locomotives (28 members).
   (a) Sub-Committee on Component Parts and Tires (14 members);
   (b) Sub-Committee on Steel Plates (7 members);
   (c) Sub-Committee on Tires, Axles and Springs (6 members);
   (d) Sub-Committee on Copper and its Alloy (6 members).

5. Rails (22 members).
    (a) Section on Railway Rails (11 members) ;
    (b) Section on Tramway Rails (4 members).
6. Electrical Plant (22 members).
    (a) Sub-Committee on Generators, Transformers and
        Motors (13 members) ;
    (b) Sub-Committee on Temperatures of Insulation
        Materials (5 members) ;
    (c) Sub-Committee on Cables and Conduits (11 mem-
        bers) ;
    (d) Sub-Committee on Telegraphs and Telephones
        (7 members).
7. Screw-Threads and Limit-Gauges (26 members).
    (a) Sub-Committee on Screw-Threads (26 members) ;
    (b) Sub-Committee on Limit-Gauges (17 members).
8. Pipe-Flanges (12 members).
9. Cement (17 members).

Three of the above-named committees have considered inde-
pendently the question of " Standard Sections for Rolled Iron
and Steel," and have held joint meetings and have agreed upon
standard sections which have been adopted and published.

It will be seen from the foregoing that the English Engineer-
ing Standards Committee is operating on lines quite similar to
those adopted by the American Society for Testing Materials.
Both have recognized the desirability of giving fair representa-
tions on their committees to all parties in interest, including the
manufacturers. The work is divided among numerous sub-
committees whose reports are submitted to the parent committee,
which in turn makes its report to the technical societies which
it represents.

The work in England is much facilitated, however, first,
from the fact that the five leading technical societies are co-
operating through the medium of a single, jointly-appointed
committee; and second, by reason of the liberal financial sup-
port which the Government has lent to the undertaking.

Notwithstanding certain disadvantages, however, the prog-
ress that has been made in this country during the past few
years towards the standardization of specifications is distinctly
creditable; and it is confidently expected that the moral and
financial support for continuing this work along broader lines
will be duly forthcoming.

# THE NEED OF STANDARD SPECIFICATIONS FOR GRAY IRON CASTINGS*

By **HENRY SOUTHER**
Hartford, Connecticut

I T is generally admitted that a good practical and commercial set of specifications for use by the many cast iron purchasers does not exist. A few good sets are in the hands of large buyers, but even these are very different, contradictory, and not intended to cover a wide range of product. Most of these sets have been written to cover one industry only.

It is strange that purchasers of cast iron have not looked into this question long ago and demanded good, uniform cast iron.

Probably cast iron has been discarded from many uses because of its failure in some few instances, even though the failure was due to ignorance of the quality of the iron, or perhaps to abnormally bad iron. It is not too extreme to say that some consider all gray iron from a given foundry alike and uniform, especially if they know it is made from certain well-known brands of iron. It is likely that with standard specifications and the increase of knowledge necessary to meet these conditions, the use of gray iron castings will enter into fresh fields because of the certainty of quality. This was the case when steel replaced wrought iron, for the reason that it was made of a uniformly good quality and was thoroughly reliable.

The foundryman, therefore, should welcome any good commercial steps taken in the direction of securing standard specifications for cast iron.

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*Atlantic City Meeting of the American Society of Mining Engineers, February, 1904.

Uniformity of product in soft steel is comparatively easy to bring about, and yet the most rigid specifications are in common use by the purchasers of this material.

Uniformity of product in cast iron is not easy to attain because of the greater quantity of impurities in it, yet specifications for soft steel are common while for cast iron they are rare.

In steel, only carbon, phosphorus and sulphur are of prime importance, manganese, silicon and copper being secondary, and all of these impurities exist in very small percentages.

In cast iron, however, silicon, sulphur, carbon and phosphorus are of vital importance and are present in comparatively large percentages. Furthermore, each impurity is capable of notably altering the quality of the metal. Manganese also as a secondary element is to be intelligently regulated to advantage.

Yet cast iron with the greatest possible variation in composition is neither watched, inspected nor tested in spite of the immense differences possible, while soft steel which may vary but little in comparison is submitted to a careful examination before it is accepted. This circumstance is not due to the fact that cast iron is not used at critical points either, because it is used in making columns, the breaking of which may wreck a building, as cast iron enters into the manufacture of high-pressure valves and fittings that may wreck a boiler or an hydraulic system, as well as into many other important uses.

Not only is cast iron subject to chemical and physical differences under normal conditions, but, like most cast metals, it is liable to have bad internal flaws and latent defects not possible to detect by any other means than a test to destruction. In many cases these defects are the indirect results of bad chemical conditions, for example, a high sulphur percentage, and it is for this reason, if for no other, that a limit to the sulphur-content should have a place in cast iron specifications.

## Process of Manufacture

In certain grades of gray iron an unusual strength is demanded, and in many instances it is convenient to make this grade in a reverberatory or air-furnace. Under the specifications submitted, either method is permitted, each being believed to be good, but unless otherwise specified, the cupola-furnace will be used. It is known that some founders produce all grades

of castings in the cupola-furnace successfully, by the intelligent use of both iron and fuel.

## CHEMICAL PROPERTIES

It is believed that light iron castings are more free from sulphur than heavy ones, because the presence of sulphur induces chill, shrinkage and such flaws as are grouped under the broad head of "dirty iron." All of these defects are more serious in light work than in heavy; the chill, because it is possible in thin iron and not in thick iron, the latter containing so much heat as to cause it to anneal itself in cooling; shrinkage, because light castings chill quickly, form a small, close grain and shrink more in consequence, whereas heavy castings cool slowly, form large, open grain and shrink much less; and flaws, because a flaw of a given size forms a much more serious defect in a light casting than in a heavy one. It is a fact that flaws induced by the presence of sulphur do not decrease in proportion to the decrease in the bulk of a casting, and it is common to find shot-holes in small castings of about the same size as those in much larger castings.

The sulphur-limits placed in these specifications are within the commercial reach of any well-regulated foundry, and necessitate no extra cost. The low sulphur-limit for heavy castings has been objected to as unnecessarily low, but it is on the safe side and is an insurance against bad flaws and should be retained, for the reason that it does not increase the cost of the iron.

Cast iron with high sulphur-content is sometimes stronger than with low, because the grain in the former instance is closer, a condition which always tends to increase the strength; but of what use is the extra strength if at some vital point in the casting flaws exist as a result of high sulphur-content, that weaken it and far more than offset the extra strength of the sound parts of the casting?

Even if it is assumed that a test-bar representing a cylinder does show unusual strength and is of high sulphur-content and sound at the point of rupture, the casting itself may contain enough shot- and blow-holes to cause failure.

A high sulphur-content is a menace in any casting, whether

it can be detected physically or not, and this impurity should be excluded as far as possible commercially.

## PHYSICAL PROPERTIES

The figures given in Table I have been taken from as many tests as was possible to accumulate in the short time available after determining the dimensions of the test-specimen. All kinds of iron are not represented, but those that are given show very encouraging results.

I was not able to get reliable information in all cases. The bars are from six foundries, making products very varied in character.

From the same foundries the results of testing the inch-square bars selected at random from recent tests are given in Table II for comparison, being tests made under exactly similar conditions. Nos. 12,761 and 12,762 were from the same ladle of metal as Nos. 12,759 and 12,760.

The theoretical ratio of strength of the inch-square bar in common use as compared with the arbitration bar is about 0.8 to 1, or, to be exact, 0.867; that is, the inch-square bar is about 80 per cent as strong as the 1¼-in. round bar, all things being equal. The results of the few tests made in both shapes from the same run are close to this, as is shown in Tables I and II. Actual results do not follow the theory exactly for the reason that the greater volume of the arbitration bar results in its being softer, all other things being equal. There is also a lesser proportion of chilled metal in the round bar.

The worst enemy of the cast iron test-specimen is the physical defect or flaw. Fewer of the round test-bars contain flaws than of the square. It is apparent that the sharp corners by capillarity or similar influences attract rising bubbles of gas and entrap them in the quicker cooling metal contained in the corners. This effect alone places the round bar superior to the square as a fair representative of a cast.

The figures given in Table I show that the transverse strength-limits are placed so low that no difficulty should be experienced in filling the requirements.

After obtaining more data it may be found that higher strength-limits are possible and advisable. With the ones given,

TABLE I. — *Results Obtained from Tests Made with Arbitration Test-Bars.*

| No. of Specimen. | Deflection in 12 Inches. | Strength. | Phosphorus. | Manganese. | Sulphur. | Silicon. |
|---|---|---|---|---|---|---|
| | Inches. | Pounds Per Sq. In. | Per Cent. | Per Cent. | Per Cent. | Per Cent. |
| 12,174 | 0.15 | 3,500 | 0.630 | 0.30 | 0.128 | 1.819 |
| 12,175 | 0.12 | 3,600 | | | | |
| 12,266 | 0.09 | 3,500 (Cast with | 0.889 | 0.60 | 0.144 | 2.383 |
| 12,267 | 0.07 | 3,200 fins.) | | | | |
| 12,269 | 0.07 | 3,200 | 0.653 | 0.18 | 0.104 | 2.040 |
| 12,270 | 0.08 | 3,200 | | | | |
| 12,343 | 0.13 | 3,300 | 0.520 | 0.36 | 0.099 | 1.683 |
| 12,344 | 0.11 | 3,000 | | | | |
| 12,345 | 0.12 | 3,200 | (These bars | had fins.) | ........ | 1.584 |
| 12,346 | 0.13 | 3,000 | | | | |
| 12,429 | 0.10 | 2,800 | 0.534 | 0.36 | 0.098 | 1.725 |
| 12,430 | 0.08 | 2,800 | | | | |
| 12,431 | 0.10 | 3,500 | (All cast | with fins.) | ........ | 1.810 |
| 12,432 | 0.10 | 3,100 | | | | |
| 12,433 | 0.13 | 3,500 | 0.340 | 0.30 | 0.113 | 1.340 |
| 12,434 | 0.11 | 3,800 | | | | |
| 12,435 | 0.11 | 3,500 | 0.364 | 0.28 | 0.101 | 1.678 |
| 12,436 | 0.12 | 3,400 | | | | |
| 12,480 | 0.14 | 3,600 | 0.681 | 0.30 | 0.105 | 2.092 |
| 12,481 | 0.12 | 3,800 | | | | |
| 12,546 | 0.07 | 3,200 | 0.562 | 0.32 | 0.095 | 1.899 |
| 12,547 | 0.11 | 3,400 | | | | 1.848 |
| 12,551 | 0.09 | 2,700 | 0.326 | 0.38 | 0.088 | 1.565 |
| 12,552 | 0.09 | 3,000 | | | | |
| 12,553 | 0.06 | 2,600 | 0.377 | 0.36 | 0.097 | 1.631 |
| 12,554 | 0.09 | 3,100 | | | | |
| 12,638 | Lost | 3,500 | 0.536 | 0.42 | 0.088 | 1.974 |
| 12,639 | 0.10 | 4,000 | 0.687 | 0.24 | 0.089 | 1.960 |
| 12,673 | 0.10 | 2,900 | 0.580 | 0.34 | 0.124 | 1.706 |
| 12,674 | 0.13 | 3,550 | | | | |
| 12,675 | 0.11 | 3,500 | ............ | ........ | ........ | 1.852 |
| 12,676 | 0.11 | 3,200 | | | | |
| 12,729 | 0.15 | 3,500 | 0.758 | 0.20 | 0.099 | 2.101 |
| 12,730 | 0.11 | 2,800 | 0.756 | 0.20 | 0.111 | 2.125 |
| 12,731 | 0.15 | 3,000 | 0.269 | 0.30 | 0.084 | 1.184 |
| 12,732 | 0.13 | 3,100 | | | | |
| 12,733 | 0.17 | 3,500 | ............ | ........ | ........ | 1.800 |
| 12,734 | 0.15 | 3,200 | | | | |
| 12,752 | 0.14 | 2,500 | 0.631 | 0.43 | 0.092 | 2.453 |
| 12,753 | 0.17 | 2,500 | (These | bars had | fins.) | |
| 12,759 | 0.10 | 4,000 | (Semi-steel.) | 0.16 | 0.170 | 1.462 |
| 12,760 | 0.10 | 4,000 | 0.382 | | | |
| 12,780 | 0.09 | 2,700 | 0.716 | 0.46 | 0.047 | 2.468 |
| 12,781 | 0.11 | 3,200 | | | | |
| 12,800 | 0.13 | 2,800 | 0.690 | 0.48 | 0.048 | 2.695 |
| 12,801 | 0.13 | 2,800 | | | | |
| 12,838 | 0.15 | 3,700 | 0.413 | 0.36 | 0.089 | 1.730 |
| 12,839 | 0.15 | 3,000 | | | | |
| 12,840 | 0.14 | 3,100 | ............ | ........ | 0.094 | 1.645 |
| 12,841 | 0.16 | 3,800 | | | | |
| 12,863 | 0.10 | 3,100 | 0.723 | 0.30 | 0.136 | 2.275 |
| 12,864 | 0.10 | 3,100 | | | | |
| 12,913 | 0.12 | 3,300 | 0.663 | 0.32 | 0.129 | 1.683 |
| 12,914 | 0.13 | 3,300 | | | | |
| 12,915 | 0.13 | 3,200 | ............ | ........ | | 1.749 |
| 12,916 | 0.08 | 2,900 | | | | |

The results bracketed together signify that the iron was from the same day's cast—sometimes ou of the same ladle, and sometimes not.

however, uniformity and good quality are insured, which is the main object to be desired at present.

No upper-strength limit has been placed as this factor is controlled by the machinery-properties of the iron. It is my opinion that a drilling-test would be the best safeguard against a too hard iron. As not enough data exist at present to make proper commercial limits, this matter is one that should be thoroughly investigated.

A minimum limit for deflection has been placed in the specifications to guard against a strong but brittle iron. Such

TABLE II. — *Results Obtained from Tests Made with 1-in. Square Bars.*

| No. of Specimen. | Cast No. | Strength. | Phosphorus. | Manganese. | Sulphur. | Silicon. |
|---|---|---|---|---|---|---|
| | | Pounds Per Sq. In. | Per Cent. | Per Cent. | Per Cent. | Per Cent. |
| 12,006 | 2 | 2,700 | 0.765 | 0.36 | 0.072 | 3.305 |
| 12,011 | 2 | 2,700 | 0.605 | 0.24 | 0.105 | 2.718 |
| 12,027 | 11/28 | 2,800 | 0.551 | 0.30 | 0.118 | 1.673 |
| 12,048 | 11/20 | 3,000 | 0.779 | 0.46 | 0.095 | 2.251 |
| 12,065 | 11/27 | 3,300 | 0.722 | 0.36 | ......... | 1.951 |
| 12,079 | 113 | 2,300 | 0.595 | 0.56 | 0.085 | 2.016 |
| 12,118 | 2 | 3,000 | 0.580 | 0.16 | 0.081 | 2.769 |
| 12,157 〉 | 206 〉 | 3,000 〉 | 0.656 〉 | 0.68 〉 | 0.082 〉 | 〉 1.894 |
| 12,158 〉 | 207 〉 | 3,000 〉 | 0.651 〉 | 0.36 〉 | 0.115 〉 | 〉 1.866 |
| 12,170 | 12/10 | 2,300 | 0.670 | 0.88 | 0.074 | 2.947 |
| 12,198 〉 | 12/5 〉 | 2,600 〉 | | | | 〉 1.434 |
| 12,200 〉 | 12/8 〉 | 2,700 〉 | 0.535 | 0.32 | 0.110 | 〉 1.640 |
| 12,202 〉 | 12/10 〉 | 2,800 〉 | | | | 〉 1.419 |
| 12,376 | 12/19 | 2,400 | 0.644 | 0.70 | 0.097 | 3.158 |
| 12,420 〉 | 214 〉 | 3,000 〉 | 0.626 〉 | 0.38 〉 | 0.085 〉 | 〉 2.031 |
| 12,421 〉 | 215 〉 | 2,500 〉 | 0.614 〉 | 0.38 〉 | 0.091 〉 | 〉 2.007 |
| 12,427 | 2 | 2,500 | 0.577 | 0.24 | 0.087 | 2.797 |
| 12,761 | ......... | 2,800 | Deflection in 12 in., | | 0.13 in. | ......... |
| 12,762 | ......... | 3,000 | Deflection in 12 in., | | 0.13 in. | ......... |

iron is not often met, but nevertheless it is a factor and should be guarded against. Some of the tests given show a lower deflection, but most of them were due to the fact that the bars were cast with a sectional mold, the attached fins being subsequently ground off; other low deflections were due to accidental defects, and in one set the directions for casting had not been followed and the bars had been roughly ground, which removed the skin in spots.

The normal specimens cast as directed were better than the

standard demanded and were as good as that warranted by the chemical composition.

## TENSILE STRENGTH TEST

Nothing new is offered in this particular. The strength limits correspond to the ordinary demands so far as made of the present trade. A uniform gripping-device should be adopted as far as possible for the reason that the grip is of vital importance in testing cast iron for tensile strength.

## DEFINITION

The classification made is approximate and will naturally be supplemented by buyers who will specify that a given casting must conform to the specifications applying to one of the grades. This will remove all uncertainty as to which class may be meant.

## ARBITRATION BAR

It was the first choice of the committee that a 1.5 in.-bar might be used, in fact, a bar that would be as large as possible in order to be free from all chilling influences and defects resulting from sudden cooling; in short, a less sensitive bar. It was seen that such a bar would break at too great a strength and be beyond the limits of the majority of testing machines now in use in foundries. A diameter of 1.25 in. was therefore adopted as being satisfactory, all things considered.

The question arose of having one standard size of test-bar as compared with having several, in order to make an approximate comparison of thicknesses with the castings under inspection and thus duplicate the actual cooling conditions. This is not possible, because any separate bar must cool more or less slowly than the casting, and any coupon-cast as a part of the casting must be machined before testing. A test of this kind made without the skin does not represent the actual casting, nor can like conditions be duplicated at will in this way.

By having a standard bar it is perfectly possible to estimate the strength of any other bar or casting, just as in the case of the steel maker who rolls a standard test-bar, say 2½ by ⅜ in. in section from a small 6 in. square test ingot, and from the results obtained is able to foretell the strength of the same steel rolled into a ⅜-in. rod, a 0.5-in. angle-iron, or a 1.25-in. plate. It

is all a question of heat treatment and speed of cooling, and in this respect cast iron is similar to steel. Cooling conditions follow very definite laws well recognized by the average founder without his analyzing the reasons. Any grade or quality of cast iron may be purchased with the arbitration test-bar as specified as well as by a dozen different sizes of test-bars. It is a matter of comparison at the best, and one standard is enough.

As a study it would be interesting to cut out specimens from all sizes of castings as far as possible, and the results would form a basis for future comparison, but as a commercial custom this suggestion is practically and commercially out of the question. The importance of the tensile test has been minimized because of the great difficulty of making true tensile tests. Abnormal strains are sure to creep in except in the most carefully constructed machines operated by the most skilled observers.

The transverse test is within the reach of all and, in fact, corresponds with the conditions of actual use much closer than does the tensile test, and no serious abnormal strains are possible with the ordinary testing machine.

The occasion is likely to arise in which the tensile test will be advisable, to meet which the provision noted in the specifications is inserted. The shape of the specimen resembles quite closely the one in use by the Government, but it has been modified to meet the needs of the piece from which it is to be cut, as well as of other practical considerations. It has been made as short as possible to eliminate the chance of including flaws, and it has been lengthened as compared with the Government specimen, which is likely to give abnormally high results.

### CONDITIONS OF CASTING

Probably the most important source of varying results in cast iron tests has been the uncertain conditions surrounding molding and casting. There never has been any uniformity in this respect, yet it is a well-known fact that cast iron is very much influenced by various chilling effects, and is extremely sensitive to all heat-variations. Some foundrymen have made the molds in sand that is quite moist and others in sand that is very dry. Some have knocked the test-bar out of the mold as quickly as it became cool enough to stand it. Some have cast

the bar on end, some flat, and some inclined, the variations being nearly as many as the number of founders. It has therefore been provided that the mold shall be dry and cool before the bar is cast and the other conditions shall be observed which will tend to produce uniform castings.

I note that by some error a provision to prevent the knocking out of the test-bar from the mold has been omitted. This provision was contained in the instructions sent for casting the bars tested, and I doubt that all the conditions were observed, for if one infringement in the matter of casting in a parted mold was made probably there were others. These differences undoubtedly account for some of the abnormal variations.

Some of the bars submitted for the test were cast in a parted mold, producing fins of greater or less thickness, which were chipped or ground off. The result of this condition was that less deflection resulted, even though the fins were placed at the neutral axis of the test specimen, and a probable loss of strength.

The provision stating that the test-bars should not be treated in any respect before testing has been found to be most important. The facing of the mold has been particularly specified, so that the test-bar shall strip from the mold in fairly good shape and be ready for the test.

TABLE III. — *Measurements of Arbitration Test-Bars at the Point of Rupture.*

| No. of Specimen | Diameter in Inches | No. of Specimen | Diameter in Inches | No. of Specimen | Diameter in Inches |
|---|---|---|---|---|---|
| 1 | 1.240 | 8 | 1.246 | 15 | 1.180 This bar cast with fins. |
| 2 | 1.241 | 9 | 1.273 | 16 | 1.236 Rounded off by grinding. |
| 3 | 1.231 | 10 | 1.231 | 17 | 1.243 |
| 4 | 1.221 | 11 | 1.234 | 18 | 1.245 |
| 5 | 1.233 | 12 | 1.242 | 19 | 1.259 |
| 6 | 1.244 | 13 | 1.220 This bar was ground smooth. | | |
| 7 | 1.236 | 14 | 1.233 | 20 | 1.238 |

The objection has been made that the bars could not be made sufficiently uniform in diameter — an effect which is more or less true when the iron is cast in a green sand mold; but with the stated casting conditions which prohibit the rapping of the

pattern and with the use of a dry mold and a given facing, this objection has almost disappeared and has become of extremely small importance. Measurements made of 20 bars show a maximum variation of but 0.039 in. in an average diameter at the break of 1.236 inches.

It is interesting to note that the only bar cast with fins, that is, in a parted mold, was the most abnormal of the lot, which ought to be considered a most excellent endorsement of the proposed method of molding.

The question of the character of the supports to be used during the test has been raised, but it is believed that little need be feared on this account, as the testing machines in common use are safe in this matter. In the tests given in Tables I and II, the point of contact where the load was applied has a radius of about 0.25 in., but no mark is left on the castings, and it is doubtful if this would cause any difference unless the edge were exceedingly sharp, or was a flat surface. The two end-bearings used were flat surfaces intended to rotate on a round bearing. The rotation was not perceptible. Either bearings of this kind, or blunt knife edges, in all probability, would answer equally well.

### SPEED OF TESTING

The time limit of the test has been placed to meet ordinary practice, as near as can be ascertained. In all events it is within reason, and as long as the practice is made uniform by different observers, it is of comparative small moment.

### SAMPLES FOR CHEMICAL ANALYSIS

This simple provision has been made with the understanding that the boring shall be taken after removing all of the surface matter. In case graphitic carbon enters into the case, the sample should be taken across the entire face or cross-section of the bar and thoroughly mixed, — a procedure which is necessary because of the difference in graphitic carbon existing between the exterior and interior metal of a specimen of the size in question.

I recognized that these specifications for gray iron castings are not ideal from every standpoint, nor is it possible that any commercial ones may be. Theory must yield to practice all along the line, and every engineer or manager discovers this fact very early in his connection with manufacturing conditions.

The Committee believes that by means of these specifications the purchaser of gray iron castings will be able to obtain a more uniform and reliable product. It is also certain that there will be correspondingly less friction, because an order for iron-castings will be definite as to quality, and if the foundry makes them to fill the specifications, there can be no dispute as to the quality of the iron furnished because some machinist thinks machines hard or thinks it looks weak.

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## SPECIFICATIONS FOR CAST IRON AND FINISHED CASTINGS*

By RICHARD MOLDENKE
New York City

AMONG the actions that will always remain to the credit of the foundry industry is the fact that nearly all of the research work of practical value to the daily routine was made by active foundrymen, and the results were freely given by them to the world. Moreover, while consumers felt that to them was due a more systematic and exact method of work, the foundrymen again were the first to act on the establishment of specifications under which their product should be sold.

To come to more recent times, the American Foundry-men's Association not only has made an elaborate series of tests upon cast iron, and adopted tentative specifications based upon them, but, in addition, it has urged the International Association for Testing Materials, through its American representatives, to make the testing and specification of cast iron a distinct issue. From a half-hearted support at the time, the rapidly growing recognition accorded to the enormous iron-casting industry compelled better attention, and when the president of the American Society for Testing Materials was instructed to ask for a special commission for the purpose, Europe was ready to coöperate. At the Buda-Pesth congress, at which America was represented by Prof. Howe, Mr. Wood and myself, it was decided to add five members to the general committee on steel and iron, whose special

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duty was to conserve the interests of the cast iron branch of the industry.

America took up the work at once, and enlarged its committee to 67 members, all of whom were actively concerned in the manufacture or study of cast iron in all of its branches. At the organization meeting in Philadelphia, April 25, 1903, Mr. Walter Wood was elected chairman, and myself secretary, and within a week thereafter the sub-committees were appointed and became active at once. The scope of the work was naturally limited to those branches of the iron-casting industry which lend themselves to standardization, and the following committees began to collect information on existing methods, and to formulate specifications based thereon as far as possible, the final results being intended to represent the best American practice at the present time.

A sub-committee was appointed for each of the following named branches of the cast iron industry: Pig iron, pipe, cylinders, car-wheels, malleable cast iron, general castings, and the testing of cast iron for quality as a metal. Subsequently two additional committees were appointed, one on the influence of additions to cast iron, and the other on the microstructure of cast iron.

The membership of these committees embraces the consumer, the producer, and the engineer, so that all three interests are represented. The result has been most satisfactory, due to the spirit of fair play, and the broad-minded view of the situation which has resulted. The American Society for Testing Materials is steadily becoming the great clearing-house of the Nation in matters relating to industrial practice, and the benefits will be incalculable.

. The specifications for pig iron were completed first, and bear the marks of the very recent radical change from the old haphazard fracture-specification, to the purchase on scientific principles. The trade-customs had to be retained to some extent, as otherwise the departure would be unintelligible to a large number of our older foundrymen, whom it is proposed to help as much as possible in getting good material. These older foundrymen would be lost if they had only machine-cast pig iron to draw from, while the modern operator wants all the metal he can get in that form.

The malleable cast iron specifications were completed next; while the testing of cast iron itself and the class of general cast-

ings had to be combined, it being the American view that where a casting cannot be tested to destruction, the next best thing to do is to get a measure of the quality of the iron in it, under conditions which are both fair and accurate.

Of these things you will hear more from the chairmen of the respective sub-committees, who have promised to present papers before this meeting.

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## SPECIFICATION FOR CAR WHEELS*

### By C. B. DUDLEY

THE wheels furnished under this specification must be made from the best materials, and in accordance with the best foundry methods. The following pattern analysis is given for information, as representing the chemistry of a good cast iron wheel. Successful wheels, varying in some of the constituents quite considerably from the figures given, may be made:



Total carbon....... 3.50 per cent
Graphitic carbon... 2.90 per cent
Combined carbon... 0.60 per cent
Silicon ............. 0.70 per cent
Manganese ........ 0.40 per cent
Phosphorus ........ 0.50 per cent
Sulphur ........... 0.08 per cent

1. Wheels will be inspected and tested at the place of manufacture.

2. All wheels must conform in general design and in measurements to drawings, which will be furnished, and any departure from the standard drawing must be by special permission in writing, and manufacturers wishing to deviate from the standard dimensions must submit duplicate drawings showing the proposed changes, which must be approved.

3. The following table gives data as to weight and tests of various kinds of wheels for different kinds of cars and service:

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*Report of the Sub-Committee of the American Society for Testing Materials, February, 1904.

| Wheel | 33-in. diameter Freight and Passenger Cars | | | 36-inch diameter | |
| --- | --- | --- | --- | --- | --- |
| Kind of service | 60,000 lbs. capacity and less | 70,000 lbs. capacity | 100,000 lbs. capacity | Passenger Cars | Locomotive Tenders |
| Number................. | 1 | 2 | 3 | 4 | 5 |
| Weight { Maximum...... | 500 lbs. | 650 lbs. | 720 lbs. | 705 lbs. | 760 lbs. |
| Weight { Minimum ...... | 560 lbs. | 610 lbs. | 670 lbs. | 680 lbs. | 720 lbs. |
| Height of Drop, ft........ | 12 | 12 | 12 | 12 | 12 |
| Number of blows ........ | 10 | 12 | 15 | 12 | 15 |

4. Each wheel must have plainly cast on the outside plate the name of the maker and place of manufacture. Each wheel must also have cast on the inside double plate the date of casting and a serial foundry number. The manufacturer must also provide for the guarantee mark, if so required by the contract. No wheel bearing a duplicate number, or a number which has once been passed upon, will be considered. Numbers of wheels once rejected will remain unfilled. No wheel bearing an indistinct number or date, or any evidence of an altered or defaced number will be considered.

5. All wheels offered for inspection must have been measured with a standard tape measure and must have the shrinkage number stenciled in plain figures on the inside of the wheel. The standard tape measure must correspond in form and construction to the "Wheel Circumference Measure" established by the Master Car Builders' Association in 1900. The nomenclature of that measure need not, however, be followed, it being sufficient if the graduating marks indicating tape sizes are one-eighth of an inch apart. Any convenient method of showing the shrinkage or stencil number may be employed. Experience shows that standard tape measures elongate a little with use, and it is essential to have them frequently compared and rectified. When ready for inspection, the wheels must be arranged in rows according to shrinkage numbers, all wheels of the same date being grouped together. Wheels bearing dates more than thirty days prior to the date of inspection will not be accepted for test, except by permission. For any single inspection and test only wheels having three consecutive shrinkage or stencil numbers will be considered. The manufacturer will, of course, decide what three shrinkage or stencil numbers he will submit in any given

lot of 103 wheels offered, and the same three shrinkage or stencil numbers need not be offered each time.

6. The body of the wheels must be smooth and free from slag and blowholes, and the hubs must be solid. Wheels will not be rejected because of drawing around the center core. The tread and throat of the wheels must be smooth, free from deep and irregular wrinkles, slag, sand wash, chill cracks or swollen rims, and be free from any evidence of hollow rims, and the throat and thread must be practically free from sweat.

7. Wheels tested must show soft, clean, gray iron, free from defects, such as holes containing slag or dirt more than one-quarter of an inch in diameter, or clusters of such holes, honeycombing of iron in the hub, white iron in the plates or hub, or clear white iron around the anchors of chaplets at a greater distance than one-half of an inch in any direction. The depth of the clear white iron must not exceed seven-eighths of an inch at the throat and one inch at the middle of the tread, nor must it be less than three-eighths of an inch at the throat or any part of the tread. The blending of the white iron with the gray iron behind must be without any distinct line of demarcation, and the iron must not have a mottled appearance in any part of the wheel at a greater distance than one and five-eighths inches from the tread or throat. The depth of chill will be determined by inspection of the three test wheels described below, all test wheels being broken for this purpose, if necessary. If one only of the three test wheels fails in limits of chill, all the lot under test of the same shrinkage or stencil number will be rejected and the test will be regarded as finished so far as this lot of 103 wheels is concerned. The manufacturer may, however, offer the wheels of the other two shrinkage or stencil numbers, provided they are acceptable in other respects as constituents of another 103 wheels for a subsequent test. If two of the three test wheels fail in limits of chill, the wheels in the lot of 103 of the same shrinkage or stencil number as these two wheels will be rejected, and, as before, the test will be regarded as finished so far as this lot of 103 wheels is concerned. The manufacturer may, however, offer the wheels of the third shrinkage or stencil number, provided they are acceptable in other respects, as constituents of another 103 wheels for a subsequent test. If all three test wheels fail in limits of chill, of course the whole hundred will be rejected.

8. The manufacturer must notify when he is ready to ship not less than 100 wheels; must await the arrival of the Inspector; must have a car, or cars, ready to be loaded with the wheels, and must furnish facilities and labor to enable the Inspector to inspect, test, load and ship the wheels promptly. Wheels offered for inspection must not be covered with any substance which will hide defects.

9. A hundred or more wheels being ready for test, the Inspector will make a list of the wheel numbers, at the same time examining each wheel for defects. Any wheels which fail to conform to specifications by reason of defects must be laid aside, and such wheels will not be accepted for shipment. As individual wheels are rejected, others of the proper shrinkage, or stencil number, may be offered to keep the number good.

10. The Inspector will retape not less than 10 per cent of the wheels offered for test, and if he finds any showing wrong tape marking, he will tape the whole lot and require them to be restenciled, at the same time having the old stencil marks obliterated. He will weigh and make check measurements of at least 10 per cent of the wheels offered for test, and if any of these wheels fail to conform to the specification, he will weigh and measure the whole lot, refusing to accept for shipment any wheels which fail in these respects.

11. Experience indicates that wheels with higher shrinkage or lower stencil numbers are more apt to fail on thermal test; more apt to fail on drop test, and more apt to exceed the maximum allowable chill than those with higher stencil or lower shrinkage numbers; while, on the other hand, wheels with higher stencil or lower shrinkage numbers are more apt to be deficient in chill. For each 103 wheels apparently acceptable, the Inspector will select three wheels for test — one from each of the three shrinkage or stencil numbers offered. One of these wheels chosen for this purpose by the Inspector must be tested by drop test as follows: The wheel must be placed flange downward in an anvil block weighing not less than 1,700 pounds, set on rubble masonry two feet deep and having three supports not more than five inches wide for the flange of the wheel to rest on. It must be struck centrally upon the hub by a weight of 140 pounds, falling from a height as shown in the table on page 416. The end of the falling weight must be flat, so as to strike fairly on the hub, and when by wear the bottom of the

weight assumes a round or conical form, it must be replaced. The machine for making this test is shown on drawings which will be furnished. Should the wheels stand, without breaking in two or more pieces, the number of blows shown in the above table, the one hundred wheels represented by it will be considered satisfactory as to this test. Should it fail, the whole hundred will be rejected.

12. The other two test wheels must be tested as follows: The wheels must be laid flange down in the sand, and a channelway one and one-half inches in width at the center of the tread and four inches deep must be molded with green sand around the wheel. The clean tread of the wheel must form one side of this channelway, and the clean flange must form as much of the bottom as its width will cover. The channelway must then be filled to the top from one ladle with molten cast iron, which must be poured directly into the channelway without previous cooling or stirring, and this iron must be so hot, when poured, that the ring which is formed when the metal is cold shall be solid or free from wrinkles or layers. Iron at this temperature will usually cut a hole at the point of impact with the flange. In order to avoid spitting during the pouring, the tread and inside of the flange during the thermal test should be covered with a coat of shellac; wheels which are wet or which have been exposed to snow or frost may be warmed sufficiently to dry them or remove the frost before testing, but under no circumstances must the thermal test be applied to a wheel that in any part feels warm to the hand. The time when pouring ceases must be noted, and two minutes later an examination of the wheel under test must be made. If the wheel is found broken in pieces, or if any crack in the plates extends through or into the tread, the test wheel will be regarded as having failed. If both wheels stand, the whole hundred will be accepted as to this test. If both fail, the whole hundred will be rejected. If one only of the thermal test wheels fails, all of the lot under test of the same shrinkage or stencil number will be rejected, and the test will be regarded as finished, so far as this lot of wheels is concerned. The manufacturer may, however, offer the wheels of the other two shrinkage or stencil numbers, provided they are acceptable in other respects, as constituents of another 103 wheels for a subsequent test.

13. All wheels which pass inspection and test will be re-

garded as accepted, and may be either shipped or stored for future shipment, as arranged. It is desired that shipments should be, as far as possible, in lots of 100 wheels. In all cases the Inspector must witness the shipment, and he must give, in his report, the numbers of all wheels inspected and the disposition made of them.

14. Individual wheels will be considered to have failed and will not be accepted or further considered, which,

*First.* Do not conform to standard design and measurement.

*Second.* Are under or over weight.

*Third.* Have the physical defects described in Section 6.

15. Each 103 wheels submitted for test will be considered to have failed and will not be accepted or considered further, if,

*First.* The test wheels do not conform to Section 7, especially as to limits of white iron in the throat and tread and around chaplets.

*Second.* One of the test wheels does not stand the drop test as described in Section 11.

*Third.* Both of the two test wheels do not stand the thermal test as described in Section 12.

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## SPECIFICATIONS FOR MALLEABLE CAST IRON*

By S. G. FLAGG, Jr.
Philadelphia, Pennsylvania



*PROCESS of Manufacture* — Malleable iron castings may be made by the open hearth, air furnace or cupola process. Cupola iron, however, is not recommended for heavy nor important castings.

*Chemical Properties.* — Castings for which physical requirements are specified shall not contain over 0.06 sulphur nor over 0.225 phosphorus.

*Physical Properties.*

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*Report of the Sub-Committee of the American Society for Testing Materials, February, 1904.

— (1) *Standard Test-Bar.* This bar shall be 1 inch square and 14 inches long, without chills and with ends left perfectly free in the mold. Three shall be cast in one mold, heavy risers insuring sound bars. Where the full heat goes into castings which are subject to specification, one mold shall be poured two minutes after tapping into the first ladle, and another mold from the last iron of the heat. Molds shall be suitably stamped to insure identification of the bars, the bars being annealed with the castings. Where only a partial heat is required for the work in hand, one mold should be cast from the first ladle used and another after the required iron has been tapped.

(2) Of the three test-bars from the two molds required for each heat, one shall be tested for tensile strength and elongation, the other for transverse strength and deflection. The other remaining bar is reserved for either the transverse or tensile test, in case of the failure of the two other bars to come up to requirements. The halves of the bars broken transversely may also be used for tensile strength.

(3) Failure to reach the required limit for the tensile strength with elongation, as also the transverse strength with deflection, on the part of at least one test, rejects the castings from that heat.

(4) *Tensile Test.* The tensile strength of a standard test-bar for castings under specification shall not be less than 42,000 pounds per square inch. The elongation measured in two inches shall not be less than two and a-half per cent.

(5) *Transverse Test.* The transverse strength of a standard test-bar, on supports 12 inches apart, pressure being applied at center, shall not be less than 3,000 pounds, deflection being at least one-half of an inch.

*Test Lugs.* — Castings of special design or of special importance may be provided with suitable test lugs at the option of the inspector. At least one of these lugs shall be left on the casting for his inspection upon his request therefor.

*Annealing.* — (1) Malleable castings shall neither be " over " nor " under " annealed. They must have received their full heat in the oven at least sixty hours after reaching that temperature.

(2) The " saggers " shall not be dumped until the contents shall at least be " black hot."

*Finish.* — Castings shall be true to pattern, free from

blemishes, scale or shrinkage cracks. A variation of 1-16 of an inch per foot shall be permissible. Founders shall not be held responsible for defects due to irregular cross sections and unevenly distributed metal.

*Inspection.* — The inspector representing the purchaser shall have all reasonable facilities given him by the founder to satisfy him that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made prior to shipment.

## NOTES ON RAIL STEEL*

### By ROBERT W. HUNT
### Chicago, Illinois

I HAVE repeatedly stated that the mechanical treatment of the metal forming a steel rail, during its manufacture, was comparatively of much greater importance than its chemical composition. Years of observation have confirmed and emphasized that fact.



The comparison of the wear of the earlier steel rails with that of later ones, and to the great disadvantage of the latter, is still being constantly made by railway officials. And while some of us, with experience covering the whole history of the manufacture of steel rails, are aware of the great differences in the conditions governing their production at various periods, I do not think the engineering world generally appreciates the direct and imperative influence those variations have had, and are having, upon the wearing quality of the rails.

In the earlier days, the steel was poured into ingots which

* Atlantic City Meeting of the American Institute of Mining Engineers, February, 1904.

would make but two 30-ft. rails of not exceeding 60 lb. weight per yard — giving a mass weighing, say about 1,400 lb., and of a section of about 12 in. square. To-day the ingots are some 22 in. square, and weigh more than 4,000 lb. Of course, the interior of the larger ingots must remain hot and liquid longer than that of the smaller ones, and from this condition arises the steel rail makers' *bête noir* — segregation of the metalloids and piping of the steel. The smallest-sectioned ingot will pipe, but with the increase of its size, so will be that of the interior cavity. This tendency existing and being well known, it would seem that rather than being ignored, especial care should be exercised to avoid the evils arising from it.

In the earlier days of steel rail making, after the ingot had been rolled down to a bloom of six or seven inches square, all cracks were carefully chipped out of it. Such defects could not be welded up by subsequent working, but if cut out to the deepest point, particularly if the forming of sharp corners was avoided, the steel would, when further rolled, draw from the bottom up; and so if the cavity was not too deep, a sound bar of rail would result. This chipping was performed under a steam hammer.. Later, if while the bar was passing between the rolls of the rail-mill defects were discovered, the rolling operation was suspended until they could be chipped out. Then, again, great care was taken that the steel bloom should not be overheated. There were from six to eight blooms, each of a size to produce one rail, charged at one time into a heating furnace; and skilled workmen attended to their heating, turning them over on the bottom of the furnace so that all sides should become of an equal temperature. If from any cause this man made a mistake, and sent his steel to the rolls in an unsatisfactorily heated condition, the head rail-roller, or some other mill official, rejected it, and it was returned to him for further treatment. This meant that more or less care was exercised on each and every rail; but the daily production was, when viewed from to-day's standpoint, quite small. The first departure was to cease chipping the blooms at the rail-rolls — the next, to make it one continuous process from the first blooming of the ingot to the finished rolling of the rails. This procedure stopped the intermediate chipping of the blooms under the steam hammer, and carried with it the rolling of more than

one length rail, that is, the rolling of a mass of steel large enough to produce more than one rail length, and the subsequent sawing of this into two or more rails.

This new method of rolling had been made possible by the introduction of more or less automatic machinery; and the daily production of a given rail-mill increased very rapidly. But I regret to say that the care which it was possible to bestow on the making of each individual rail decreased in an even greater ratio, — an effect which was inevitable.

In the old days, a Bessemer converting-house was equipped with two converters, each of about five tons capacity, which were gradually enlarged to 7, 10, 15, and even 20 tons, and additional converters added. Of course, the size of the house, blowing-engines, cranes, etc., were all proportionately increased and the development of the plant has proceeded until, instead of about 12,000 tons of ingots per month coming out of one converting-house, more than 70,000 tons per month are now produced. There is more and larger machinery, and it has been said such large product is the best evidence that everything must have been running smoothly. That is true so far as mere production goes; but the speed and momentum are against the exercise of the proper kind of care necessary to produce sound ingots of the highest quality of steel. This is old-fashioned doctrine, but it is true. What are we going to do about it? I am not at all certain that I know; but I do think that the condition should not be tacitly accepted, and no effort made toward better things.

Of course, if the same radical course should be pursued with rail-ingots as is done with those intended for ordnance, armor or heavy shafting-purposes, by which the upper portion of each ingot, amounting to quite one-fourth of its entire weight, is cut off and treated as scrap, we know the greatest danger from segregation and piping would be eliminated. But this procedure will reduce the output of finished rails, and in that and other ways add much to the cost of making them. But if it is necessary in order to obtain safe rails, should not the situation be boldly faced? If railways must pay more money, and can by so doing secure rails which will not only be safe against breakage under traffic, but also give better wear, will it not be economy for them to make the greater investment? That would be one way to meet the difficulty, but I believe there are others also.

Alexander L. Holley had more to do with the introduction in America of the Bessemer process for making steel than any other man; and, later, probably did more than any one else to make possible its greatly increased and cheapened output. Some years after that process was firmly established in this country, the Siemens-Martin or open-hearth process was developed, and Mr. Holley was convinced that it also had a great future in America. So outspoken was he in support of this, that on one occasion an intimate associate of his, and one of the " Bessemer Family of Boys," said to him: " It sounds strange for you, of all men, to advocate so strongly the merits of the open-hearth process." He replied: " You mark my words, the open-hearth process will live to attend the funeral of the Bessemer process in America."

There are a number of the " Boys " still alive, and great changes along the line of Holley's prophetic vision have occurred; so that to them its fulfilment does not seem as improbable as when it was made.

In my judgment, the one question of ore-supply will, in time, compel the increased use in this country of the basic open-hearth process. We cannot forever continue the rejection of ores which are in every other quality suitable for steel making, because their phosphorus-content is outside of the Bessemer limit. And if at the same time, by the use of the other process, we produce a better metal, at cost not much if any greater, the outcome is inevitable.

Phosphorus is the controlling element in rail-steel. If that can be practically disregarded, no one will deny the ability to make a better article, no matter for what purpose it may be intended.

So far as rails are concerned, the theory relating to the difference in the wear of the steel made by the two processes is being subjected to the crucial test of practice. But no matter what steel is used, care must be exercised in making it; in pouring the ingots; in their handling and heating; and in the rolling and straightening of the rails.

While I have at different times prepared and presented to this Institute specifications for the manufacture of rails, I feel that under all the existing conditions the present is not the time for the adoption of any specification as standard. For the last few years, commercial conditions have been such that there has been practically but one side to the market. Such is not now

exactly the case. The rails of heavy sections have not been giving the anticipated service. Both Bessemer and Basic Open-Hearth rails are being made in America, and placed in service, side by side. Foreign rails of both Basic and Acid Bessemer steel have been imported. Several of the large railway systems have contracted for rails under somewhat new specifications. Let us, before saying which or any are the best, await results of actual experience. But I repeat, no matter what chemical formula, or which process of making steel, is selected, unless care in manufacture is exercised all will have been in vain.

## STANDARD SPECIFICATIONS FOR CAST IRON PIPE *

### By WALTER WOOD
#### Philadelphia, Pennsylvania

THE specifications that are submitted with this paper are practically the out-growth of those which were originally adopted by Mr. Kirkwood of Brooklyn about 1860. They have been changed but little since that time. The mode of testing pipe in the hydraulic press and the method of coating have not been departed from.

The chief addition to the specifications has been in the adoption of a test-bar 2 in. by 1 in., broken between 24 in. supports by a transverse strain applied on the flat side. Test-bars were first inserted in pipe specifications about the year 1870. At that time it was a tensile specimen to stand 16,000 lbs. per square inch.

The present bar was adopted in order to give some idea as to the deflection of the iron that was being used.

These tests have been so satisfactory to both engineers and manufacturers, and meet the requirements of the pipe trade so accurately that it is considered best to hold to the 2 in. by 1 in. bar instead of adopting the short arbitration bar, which yields but little information from the standpoint of deflection.

The new feature in these specifications is the effort to reach standards to which pipe shall be cast in the future, thus permitting the manufacturer to make up stock and the purchaser to find material on hand when he asks for deliveries. Heretofore there

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* Atlantic City Meeting of the American Institute of Mining Engineers, February, 1904.

has never been any standard weight for pipes, although in some sizes, certain weights are more frequently asked for than others. Still, as yet, no weights have ever been entitled to be considered as standard.

The fixing of standards for pipes permits the adoption of definite standards for fittings. It has been aimed to secure such uniformity for fittings that will permit of the same class of fittings covering two or more classes of pipe.

In order to accomplish this the specifications provide that pipe below 30 inches shall be made to standard outside diameters; the variation of weights between the classes to be obtained by changing the size of the core. The details governing these adjustments can best be understood by a careful reading of the annexed specifications.

In closing, it will be well to state that the various details of these specifications have been reached through several extended conferences between water engineers using pipe and pipe manufacturers, and are aimed to cover the requirements of both the user and maker.

There was one point of difference which it is to be regretted could not be adjusted, namely, the desirability of casting the smaller pipe with spigot ends down, so that this portion of the pipe should be certain to contain the closest and densest metal. The engineers, however, insisted upon the spigot end being cast upward. How far this point will be adjusted between manufacturers and users at future conferences remains to be seen.

*Description of Pipes.* — Section 1. The pipes shall be made with hub and spigot joints, and shall accurately conform to the dimensions given in Tables Nos. 1 and 2. They shall be straight and shall be true circles in section, with their inner and outer surfaces concentric, and shall be of the specified dimensions in outside diameter. They shall be at least 12 feet in length, exclusive of socket. For pipes of each size from 4-inch to 24-inch, inclusive, there shall be two standards of outside diameter, and for pipes from 30-inch to 60-inch, inclusive, there shall be four standards of outside diameter, as shown by Table No. 2.

All pipes having the same outside diameter shall have the same inside diameter at both ends. The inside diameter of the lighter pipes of each standard outside diameter shall be gradually increased for a distance of about 6 inches from each end of the

pipe so as to obtain the required standard thickness and weight for each size and class of pipe.

Pipes whose standard thickness and weight are intermediate between the classes in Table No. 2 shall be made of the same outside diameter as the next heavier class. Pipes whose standard thickness and weight are less than shown by Table No. 2 shall be made of the same outside diameter as the Class A pipes, and pipes whose thickness and weight are more than shown by Table No. 2 shall be made of the same outside diameter as the Class D pipes.

For pipes 4-inch to 12-inch, inclusive, one class of special castings shall be furnished, made from Class D pattern. Those having spigot ends shall have outside diameters of spigot ends midway between the two standards of outside diameter as shown by Table No. 2, and shall be tapered back for a distance of 6 inches. For pipes from 14-inch to 24-inch, inclusive, two classes of special castings shall be furnished, Class B special castings with Classes A and B pipes, and Class D special castings with Classes C and D pipes, the former to be stamped " AB " and the latter to be stamped " CD." For pipes 30-inch to 60-inch, inclusive, four classes of special castings shall be furnished, one for each class of pipe, and shall be stamped with the letter of the class to which they belong.

*Allowable Variation in Diameter of Pipes and Sockets.* — Section 2. Especial care shall be taken to have the sockets of the required size. The sockets and spigots will be tested by circular gauges, and no pipe will be received which is defective in joint room from any cause. The diameters of the sockets and the outside diameters of the bead ends of the pipes shall not vary from the standard dimensions by more than 0.06 of an inch for pipes 16 inches or less in diameter; 0.08 of an inch for 18-inch, 20-inch and 24-inch pipes; 0.10 of an inch for 30-inch, 36-inch and 42-inch pipes; 0.12 of an inch for 48-inch, and 0.15 of an inch for 54-inch and 60-inch pipes.

*Allowable Variation in Thickness.* — Section 3. For pipes whose standard thickness is less than 1 inch the thickness of metal in the body of the pipe shall not be more than 0.08 of an inch less than the standard thickness, and for pipes whose standard thickness is 1 inch or more, the variation shall not exceed 0.10 of an inch, except that for spaces not exceeding 8 inches in length in

any direction, variations from the standard thickness of 0.02 of an inch in excess of the allowance above given shall be permitted.

For special castings of standard patterns a variation of 50 per cent greater than allowed for stright pipe shall be permitted.

*Defective Spigots may be Cut.* — Section 4. Defective spigot ends on pipes 12 inches or more in diameter may be cut off in a lathe and a half-round wrought-iron band shrunk into a groove cut in the end of the pipe. Not more than 12 per cent of the total number of accepted pipes of each size shall be cut and banded, and no pipe shall be banded which is less than 11 feet in length, exclusive of the socket.

In case the length of a pipe differs from 12 feet, the standard weight of the pipe given in Table No. 2 shall be modified in accordance therewith.

*Special Castings.* — Section 5. All special castings shall be made in accordance with the cuts and the dimensions given in the table forming a part of these specifications.

The diameters of the sockets and the external diameters of the bead ends of the special castings shall not vary from the standard dimensions by more than 0.12 of an inch for castings 16 inches or less in diameter; 0.15 of an inch for 18-inch, 20-inch and 24-inch; 0.20 of an inch for 30-inch, 36-inch and 42-inch, and 0.24 of an inch for 48-inch, 54-inch and 60-inch. These variations apply only to special castings made from standard patterns.

The flanges on all manhole castings and manhole covers shall be faced true and smooth, and drilled to receive bolts of the sizes given in the tables. The manufacturer shall furnish and deliver all bolts for bolting on the manhole covers, the bolts to be of the sizes shown on plans and made of the best quality of mild steel, with hexagonal head and nuts, and sound, well-fitting threads.

*Marking.* — Section 6. Every pipe and special casting shall have distinctly cast upon it the initials of the maker's name. When cast especially to order, each pipe and special casting larger than 4-inch may also have cast upon it figures showing the year in which it was cast and a number signifying the order in point of time in which it was cast, the figures denoting the year being above and the number below, thus:

|      1901       |      1901       |      1901       |
|      1          |      2          |      3          |

etc., also any initials, not exceeding four, which may be required

by the purchaser. The letters and figures shall be cast on the outside and shall be not less than 2 inches in length and ⅛ of an inch in relief for pipes 8 inches in diameter and larger. For smaller sizes of pipes the letters may be 1 inch in length. The weight and the class letter shall be conspicuously painted in white on the inside of each pipe and special casting after the coating has become hard.

*Allowable Percentage of Variation in Weight.* — Section 7. No pipe shall be accepted the weight of which shall be less than the standard weight by more than 5 per cent for pipes 16 inches or less in diameter, and 4 per cent for pipes more than 16 inches in diameter, and no excess above the standard weight of more than the given percentages for the several sizes shall be paid for. The total weight to be paid for shall not exceed for each size and class of pipe received the sum of the standard weights of the same number of pieces of the given size and class by more than 2 per cent.

No special casting shall be accepted the weight of which shall be less than the standard weight by more than 10 per cent for pipes 12 inches or less in diameter, and 8 per cent for larger sizes, except that curves, Y pieces and breeches pipe may be 12 per cent below the standard weight and no excess above the standard weight of more than the above percentages for the several sizes will be paid for. These variations apply only to castings made from the standard patterns.

*Quality of Iron.* — Section 8. All pipes and special castings shall be made of cast iron of good quality, and of such character as shall make the metal of the castings strong, tough and of even grain, and soft enough to satisfactorily admit of drilling and cutting. The metal shall be made without any admixture of cinder iron or other inferior metal, and shall be remelted in a cupola or air furnace.

*Tests of Material.* — Section 9. Specimen bars of the metal used, each being 26 inches long by 2 inches wide and 1 inch thick, shall be made without charge as often as the engineer may direct, and, in default of definite instructions, the contractor shall make and test at least one bar from each heat or run of metal. The bars, when placed flatwise upon supports 24 inches apart and loaded in the center, shall for pipes 12 inches or less in diameter support a load of 1,900 pounds and show a deflection of not less than 0.30 of an inch before breaking, and for pipes of sizes larger than 12

inches shall support a load of 2,000 pounds and show a deflection of not less than 0.32 of an inch. The contractor shall have the right to make and break three bars from each heat or run of metal, and the test shall be based upon the average results of the three bars. Should the dimensions of the bars differ from those above given, a proper allowance therefor shall be made in the results of the tests.

*Casting of Pipes.* — Section 10. The straight pipes shall be cast in dry sand molds in a vertical position. Pipes 16 inches or less in diameter shall be cast with the hub end up or down, as specified in the proposal. Pipes 18 inches or more in diameter shall be cast with the hub end down.

The pipes shall not be stripped or taken from the pit while showing color of heat, but shall be left in the flasks for a sufficient length of time to prevent unequal contraction by subsequent exposure.

*Quality of Castings.* — Section 11. The pipes and special castings shall be smooth, free from scale, lumps, blisters, sand holes and defects of every nature which unfit them for the use for which they are intended. No plugging or filling will be allowed.

*Cleaning and Inspection.* — Section 12. All pipes and special castings shall be thoroughly cleaned and subjected to a careful hammer inspection. No casting shall be coated unless entirely clean and free from rust, and approved in these respects by the engineer immediately before being dipped.

*Coating.* — Section 13. Every pipe and special casting shall be coated inside and out with coal-tar pitch varnish. The varnish shall be made from coal tar. To this material sufficient oil shall be added to make a smooth coating, tough and tenacious when cold, and not brittle nor with any tendency to scale off.

Each casting shall be heated to a temperature of 300 degrees Fahrenheit immediately before it is dipped, and shall possess not less than this temperature at the time it is put in the vat. The ovens in which the pipes are heated shall be so arranged that all portions of the pipe shall be heated to an even temperature. Each casting shall remain in the bath at least five minutes.

The varnish shall be heated to a temperature of 300 degrees Fahrenheit (or less if the engineer shall so order), and shall be maintained at this temperature during the time the casting is immersed.

Fresh pitch and oil shall be added when necessary to keep the mixture at the proper consistency, and the vat shall be emptied of its contents and refilled with fresh pitch when deemed necessary by the engineer. After being coated the pipes shall be carefully drained of the surplus varnish. Any pipe or special casting that is to be recoated shall first be thoroughly scraped and cleaned.

*Hydrostatic Test.* — Section 14. When the coating has become hard, the straight pipes shall be subjected to a proof by hydrostatic pressure and, if required by the engineer, they shall also be subjected to a hammer test under this pressure.

The pressure to which the different sizes and classes of pipes shall be subjected are as follows:

|  | 20-Inch Diameter and Larger Pounds per Sq. Inch | Less than 20-inch Diameter Pounds per Sq. Inch. |
|---|---|---|
| Class A Pipe................. | 150 | 300 |
| Class B Pipe................. | 200 | 300 |
| Class C Pipe................. | 250 | 300 |
| Class D Pipe................. | 300 | 300 |

*Weighing.* — Section 15. The pipes and special castings shall be weighed for payment under the supervision of the engineer after the application of the coal-tar pitch varnish. If desired by the engineer, the pipes and special castings shall be weighed after their delivery, and the weights so ascertained shall be used in the final settlement, provided such weighing is done by a legalized weighmaster. Bids shall be submitted and a final settlement made up on the basis of a ton of 2,000 pounds.

*Contractor to Furnish Men and Materials.* — Section 16. The contractor shall provide all tools, testing machines, materials and men necessary for the required testing, inspection and weighing at the foundry of the pipes and special castings; and, should the purchaser have no inspector at the works, the contractor shall, if required by the engineer, furnish a sworn statement that all of the tests have been made as specified, this statement to contain the results of the tests upon the test-bars.

*Power of Engineer to Inspect.* — Section 17. The engineer

shall be at liberty at all times to inspect the material at the foundry, and the molding, casting and coating of the pipes and special castings. The forms, sizes, uniformity and conditions of all pipes and other castings herein referred to shall be subject to his inspection and approval, and he may reject, without proving, any pipes or other casting which is not in conformity with the specifications or drawings.

*Inspector to Report.* — Section 18. The inspector at the foundry shall report daily to the foundry office all pipes and special castings rejected, with the causes for rejection.

*Castings to be Delivered Sound and Perfect.* — Section 19. All the pipes and other castings must be delivered in all respects sound and conformable to these specifications. The inspection shall not relieve the contractor of any of his obligations in this respect, and any defective pipes or other castings which may have passed the engineer at the works or elsewhere shall be at all times liable to rejection when discovered, until the final completion and adjustment of the contract; provided, however, that the contractor shall not be held liable for pipes or special castings found to be cracked after they have been accepted at the agreed point of delivery. Care shall be taken in handling the pipes not to injure the coating, and no pipes or other material of any kind shall be placed in the pipes during transportation or at any time after they receive the coating.

*Definition of the Word " Engineer."* —Section 20. Wherever the word " engineer " is used herein it shall be understood to refer to the engineer or inspector acting for the purchaser and to his properly authorized agents, limited by the particular duties intrusted to them.

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## STANDARD SPECIFICATIONS FOR CYLINDERS *

By WALTER WOOD
Philadelphia, Pennsylvania

THESE specifications have been prepared so that castings such as locomotive and similar cylinders (upon the successful use of which so much depends) shall be made to standards that will yield good results.

The requirements to be borne in mind after the essentials

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which go with a sound and perfect casting, are those surrounding the quality of the material. These have been ascertained from actual practice of the largest users, — representatives of the American Locomotive Co., The Baldwin Shops, and the Pennsylvania Railroad being upon the Committee.

The results called for by the test-bar have been carefully checked up by actual experiment upon metal that has given satisfactory service in cylinders.

The analysis has also been determined by long experience to be one that will yield a strong iron and of a composition that will give dense and hard wearing surface.

It has been possible to make the specifications short and simple, yet covering the essential points thoroughly and definitely, as will be seen by a careful reading of the same.

## LOCOMOTIVE CYLINDERS

*Process of Manufacture.* — Locomotive cylinders shall be made from good quality of close-grained gray iron cast in a dry sand mold.

*Chemical Properties.* — Drillings taken from test pieces cast as hereafter mentioned shall conform to the following limits in chemical composition:

Silicon.................. from 1.25 to 1.75 per cent
Phosphorus................... not over 0.9   per cent
Sulphur..................... not over 0.10 per cent

*Physical Properties.* — The minimum physical qualities for cylinder iron shall be as follows:

The "Arbitration Test-Bar," 1¼ inches in diameter, with supports 12 inches apart, shall have a transverse strength not less than 2,700 pounds, centrally applied, and a deflection not less than 0.08 of an inch.

*Test Pieces and Method of Testing.* — The standard test shall be 1¼ inches in diameter, about 14 inches long, cast on end in dry sand. The drillings for analysis shall be taken from this test piece, but in case of rejection the manufacturer shall have option of analyzing drillings from the bore of the cylinder, upon which analysis the acceptance or rejection of the cylinder shall be based.

One test piece for each cylinder shall be required.

*Character of Castings.* — Castings shall be smooth, well cleaned, free from blowholes, shrinkage cracks or other defects, and must finish to blue-print size.

Each cylinder shall have cast on each side of saddle manufacturer's mark, serial number, date made and mark showing order number.

*Inspector.* — The inspector representing the purchaser shall have all reasonable facilities afforded to him by the manufacturer to satisfy himself that the finished material is furnished in accordance with these specifications. All tests and inspections shall be made at the place of the manufacturer.

## A DECADE IN AMERICAN BLAST-FURNACE PRACTICE*

By F. LOUIS GRAMMER
Baltimore, Maryland

THE iron industry has been so markedly the cynosure of all eyes, that a sense of weariness has overtaken many onlookers, and a new wonder is desired.

While the commercial phase of the iron industry has necessarily engrossed the public attention and probably is the more worthy of record, still the mechanical and metallurgical phases have recorded conspicuous advances and merit attention.

In order to appreciate the present condition of blast-furnace practice, it is necessary before enumerating the advances made during the past decade to give a brief discussion of the tendencies in the methods of administration as well as the conditions governing supremacy, for these factors have modified the aims of the manager.

It might also be well to apologize for a record of the advances made during such a short period as a decade, were it not that, for the individual, time is marked as much by the impressions recorded on the brain as by the jumps of the second hand of a watch. Furthermore, this article is written in order to carry out a project of the late Dr. Egleston, to have a record made each decade. I regret that the data collected by him, and forwarded to me, end with 1896, and therefore do not include the interesting

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* Atlantic City Meeting of the American Institute of Mining Engineers, February, 1904.

results which followed the introduction of Mesabi ores.    The
perusal of the notes is melancholy reading, somewhat like the feel-
ings we experience in going through a graveyard.    It is a record
made up of so many plants, which have ceased to be factors in the
iron world, if they are not entirely moribund.    Historically, they
would be interesting, emphasizing as they do the abnormal and
somewhat overestimated importance of furnace lines, taken with-
out proper reference to volume of blast and nature of stock used.
I regret, however, that the time at my disposal does not permit
of this presentation.

Nowadays, the administration at some plants is such that the
superintendent has become a train-dispatcher or a burden-clerk;
and this is particularly the case in those plants in which the en-
gineering duties have been divorced from the executive functions
of the superintendent, and where the preparation of ores is made
at the mine rather than at the plant. At such plants, usually con-
sisting of four or more units, the proper feeding of the furnaces
with a mixture, which the past has demonstrated will not make
it ill, has become one of the superintendent's primary duties.    The
traffic management also is important and at several plants, run-
ning from 3,000 to 14,000 tons of raw material daily, excluding
metal made, is equal in tonnage to that of many railroads.    In
addition to the traffic consideration, the cost and supplying of
labor in these troublesome labor times is properly deemed ample
responsibility for the superintendent.

This distribution of duties is in line with the general tend-
ency of the age to differentiate the duties of the laborer and the
under executive, as well as to integrate between wider limits the
responsibilities of the fewer and more powerful higher executives,
and has resulted in many benefits and some colossal errors.    It has
required the superintendent to be more a reader of events and
men, while the engineer becomes more concerned with new de-
vices to harness nature.

In the most powerful companies, this division of duties has
usually resulted in good, but in those plants, like Saxe's razors,
" made to sell," many mistakes have been made.

We can look around and see plants well arranged to make
iron, but no iron mines to supply them.    Others have fine mills,
but no furnaces; others, no market.    And so the whole decalogue
of managerial sins, resulting from a bureaucracy or directorate of
untrained iron men, can be run.

While largely due to perfected means of communication, the present state of affairs is indirectly traceable to the Bessemer process, whose Gargantuan appetite suggested the assembling of a large number of units near together. It affords a picture presenting marked contrasts to the time of Baron Stigel, whose return home, after an absence, was heralded by bonfires from the hill-tops and the booming of cannon. It was a paternal management and included such diverse industries as charcoal burning, road-building, farm-management, pottery-making and forge-running; a Pooh-Bah list of duties, picturesque, if not conducive to the rapid development of an industry! His contract that a rose a year should be deposited on his grave forever, at a church in Manheim, Pa., in lieu of a ground rent, is not one that we imagine the iron masters of to-day would make.

The present conditions are even very different from the management under the Coleman family, so long a powerful and beneficent influence in the industrial world. Their manager was regarded as a family retainer with interests permanently identified with the family welfare. Under their employ the superintendents were as much engineers as managers.

The Bessemer process, by inaugurating the general policy that each process is the servant of the succeeding process, made the furnace the servant of the converter, and the converter of the rail-mill; and in the other direction the coke-oven and the ore-mine bore the burden of the furnace superintendent's criticisms. A marked instance of this is told by a Mr. C., who ran the furnaces for a large plant in the middle West. At one time, he was being hauled over the coals rather roughly by the owner, because the mill was not getting the silicons it wanted. At last in petulance he said, " Are there no rights of the furnaces that the mill is bound to respect?" The answer received was final, " Not one."

Such a condition of affairs made the furnace superintendent's prestige depart, and his responsibilities are aptly described by one manager as being limited to the coke-barrow and the tapping-hole. On the other hand, the mechanical engineer and accountant came to the front.

As a result of those changed conditions we now find casting-machines introduced at plants where the highest mechanical efficiency is represented by a clever use of wedge, sledge and crow-bar. We find automatic chargers used where the double-ring bell

used so successfully by Mr. Firmstone and others should be used. We find the 100-ft. furnace treating magnetic ores and having a number of moves, which as managers and metallurgists we were taught to deplore. In short, if the advances became more rapid they were not always judiciously balanced. The pressure of fashion is so great that many do not consider whether it is personally becoming; in fact, local conditions are ignored.

On the strategic side we find, whereas formerly the ownership of a good ore-property and a good location near the market were supposed to be all that is necessary for manufacturing independence, now, one should own the cars, coke-ovens, coal-mines and frequently the railroad and the stone-quarries, as well as the plant of your former purchaser.

Therefore, at the plant not independent of fuel supply, or whose fuel is expensive, fuel-economy is the first consideration, while at the plant in a disturbed labor market, labor-saving devices are of a paramount importance, and at the plant which controls the market, the size of the output is the first virtue. Obviously, with such a variety of aims the chief requirement of one plant may be of secondary importance at another.

In looking over the development of furnace-practice, four steps or incidents appear as the more important factors: (1) The use of waste-gas under boilers; (2) the heating of the blast; (3) the use of coke as a fuel; and (4) the use of Lake ores. Each of these steps has resulted in a doubling and trebling of the output which was possible before their introduction.

Of course, improved refractory materials and better engines were essential, as was also a knowledge of chemistry, but these influences should be regarded as secondary and logical sequences to the others. The better application of the knowledge classified under these four heads represents the development in America.

The earlier volumes of our " Transactions " are replete with papers concerning the analysis and fusibility of slags, scaffolds, frozen furnaces, titaniferous ores, dirty walls, sulphur in metal and a host of troubles resulting from a scattered and imperfect knowledge and an uncontrolled condition. As the facts became clearly known, men avoided trouble on the principle that " prevention is better than cure."

A decade ago lines of furnaces and cooling devices occupied the thoughts of the furnace world. Since then the advances made may be classified as follows:

(1) Conveyors and other mechanical improvements.

(2) Metallurgical by-products.

(3) Miscellaneous.

Exigency of space precludes all but a simple mention of many of the steps, as a division of duties has been attended by a flood of ideas developed along the avenues where the intrusive finger of modern accounting has shown that leaks existed and improvements could be made.

*Mechanical Conveyers.* — The use of Lake ores increased tonnage so rapidly that the simple handling of ore, coke and stone became a serious problem, and, as the properties became more and more under one control, the unnecessary moves of ore into boats to be unloaded onto docks, and to be again reloaded, were reduced. Steam-shovels, like the Marion, Bucyrus and the Thew, were used to dig the ore out of the mines and to transfer it from the stock pile into the car. Messrs. Hughlett, McMyler, Hoover & Mason, and the Brown Conveying Co., devised means of economically unloading the ore from vessels of many hatches. By means of these devices, and large piers at the shipping points, the hours when the boats were idle were minimized.

The rolling-mill principle of keeping the passes of the rolls full of metal, and the transportation-virtue of keeping as many trains to the mile as is compatible with safety, was applied to the movement of the raw materials from the mines to the furnace. The steel cars reduce the cost of unloading by their steep bottoms, and these, with the bin-system, as at Duquesne, and car overturners and bridges, as at Youngstown, represent the chief changes in the matter of handling raw material.

Mr. Axel Sahlin, in our " Transactions," has comprehensively sketched the general points of mechanical transportation in detail, and it is therefore not necessary to enlarge upon them in this paper.

In moderate climates, where labor is expensive or troublesome, the devices have frequently paid well, and are sometimes necessary where the season for bringing the ore from mine to furnace is limited. Personally, I think that the skip-hoist, the last labor-saving step before the raw material enters the furnace, has not infrequently been introduced where the double-ring bell would have been better; this restriction, however, is not applicable to the general run of Lake ores.

Messrs. Walter Kennedy, M. A. Neeland and E. G. Rust designed skip-hoists which may be regarded as representing the three types. Mr. Walter Kennedy's descending-bucket passes at the side of the ascending-bucket, and acts to some extent as a counter balance; in the hoist of Mr. Neeland, one bucket only is used, and in that designed by Mr. Rust, the ascending and descending buckets pass over and under each other.

*Use of Wash-Ores.* — Mr. Firmstone showed me some charts of silicon and sulphur in basic metal made from wash-ores varying from 10 to 12 per cent silica, which in their regularity and percentage of off-cast compared very favorably with the best practice in Pittsburg; the furnace using these ores was equipped with a double-ring bell. I believe that such regularity with material of this character will astonish most of the Pittsburg iron-makers.

*Valves.* — In the question of valves, some attempt has been made to improve on the Mushroom and Berg valve-seat, the Spearman and Kennedy burner, and the cold-blast valve; save that they are made somewhat thicker and larger, they are substantially as they were a decade ago. The cutting action of Mesabi ore has suggested the multiplication of false seats and flanges on the stoves.

*Tap-Hole Gun.* — The Vaughn gun makes the work of stopping the hole easier on the men and is especially satisfactory if operated by compressed air.

*Direct Process.* — The extensive adoption of that very important link in the iron-plant — the direct process and the mixer — has suggested the undesirability of carrying a gang of specialized workmen all the week simply to carry out and break the iron on Sunday, when the converter is idle. This condition of practice has resulted in the invention of casting-machines.

*Casting-Machines.* — Mr. James Scott and Mr. Uehling have cojointly perfected the Uehling casting-machine, which is a monument to their perseverance in overcoming many obstacles. The Heyl & Paterson conveyer uses lamp-black in place of lime, and pressed steel pans in place of cast iron ones. I have always found the electric breaker at Duquesne, if used in connection with the iron-chills, less expensive and more satisfactory, though the iron cast in it is not so easily handled nor so attractive in appearance. Pig iron casting-machines require more attention and are more easily thrown out of order than the electric breaker. Besides the

above mentioned there are the Davies & Aiken pig iron casting-machines, whose merits commend them to some. The iron-chills were necessary because of the rapid growth of the basic process, in which sand and silica are most objectionable materials. In addition, the use of iron-chills saves the labor of molding the pig-bed in sand, and from them the idea was extended of making the runners and the skimmer of iron; the latter to a great extent doing away with boils.

*Slag-Car.* — The Weimar slag-cars, lined with iron thimbles, have been introduced practically to the exclusion of all others.

*Slag Disposal.* — In a few plants the slag is run into pits and granulated, and then lifted onto cars by means of cranes and orange-peel buckets. This method is very economical and is especially applicable when it is necessary to dump the cinder at a great distance from the plant, more especially if it can be utilized for manufacture into cement. One disadvantage of granulating the slag is that it may cause annoyance by creating a cloud of steam at the time of casting the iron. In some plants the slag is run into dishes, or metal pans, working on a conveyer, and after it cools it is broken up and carried away for use as railroad-ballast, a method which is advisable if the slag is non-slacking.

*Recording-Gauges, etc.* — The introduction of more recording-gauges for steam, air-blast, vacuum-pressure, and temperatures of blast and escaping furnace-gases, marks the advance of furnace practice into a state of better control.

The extensive introduction of the direct process and the pig casting-machine has, in a few cases, caused the abandonment of the cast-house, except a small building which is required to cover the cinder and the iron in their passage to the ladles.

*Dust-Pockets.* — The use of Mesabi ores has made an increase in the number of dust-pockets on the gas-main. These pockets as well as the dust-catcher are now suspended above a track, so that when the pockets are dumped the dust will fall into the cars which have been run underneath them.

*Ladle Drying.* — The iron-ladles, in the absence of natural gas, are frequently dried out by burning the blast-furnace gas brought to them in a small flue.

*Gas-Flues.* — In a few American plants the gas-flues are not lined with brick, but the great majority use cheap fire-brick and do not copy foreigners in this practice.

At some places, as at Braddock, a satisfactory water-seal valve is used to isolate a furnace from others on a common system of gas-flues, for which purpose the Rothoff valve is extensively used.

*Gas-Mains.* — Almost all gas-mains are now overhead, and underground mains are avoided. Not only is the steam system universal in the modern plant, but the tendency is to make the gas-flues universal. If one of the furnaces is cold and its gas, therefore, not suited for stoves, the gas from the three other furnaces in the system will help to maintain the stove heat on the one that needs it; in a similar manner the gases from the many furnaces tend to keep the steam-pressure regular.

*Boilers.* — The introduction of water-tube boilers marks the further attempt to obtain the full power-possibility of the escaping gas; the Babcock & Wilcox, the Sterling, the Cahall being those the most generally adopted. The numerous water-softeners, generally based on the principle of having the carbonates precipitated by lime and the sulphates decomposed by soda, have enabled water-tube boilers to be more extensively introduced. The old idea that because there is an excess of gas and on account of the ease with which scale can be removed, cylindrical boilers should be used, has passed away.

*Use of Compressed Air.* — Compressed air in place of steam is being quite extensively used for such purposes as the operation of the furnace-bell and the mud-gun. It does away with the danger of burning the men and of having the water condensed around the tapping-hole and freezing around the furnace-top.

*Steam-Pressure.* — The economies in the use of blast-furnace gas have become so extended that we now economize also on the steam obtained from the gas. In place of the 80-lb. pressure of 12 years ago, and the 60-lb. pressure of a decade earlier, we now use from 120 to 150 lb. steam-pressure in connection with compound engines, condensers and feed-water heaters. The engines are of heavy frame and the air-valves are positive acting, which gives a higher efficiency of delivery.

Without the modern engine-equipment it is probable that the present phenomenal outputs could not have been attained. Despite the fact that a finely divided ore is reduced more rapidly than a lumpy coarse ore, its use requires a greater blast-pressure, and a larger volume of blast, else its fineness will not be taken advantage

of; therefore, if the increased pressure and volume could not be supplied, the output would be smaller than when using lump ores.

I remember visiting a plant where this fact was not appreciated by the owner. It had too many engines and too many boilers, but the furnace could not get a sufficient quantity of blast to satisfy its hearth area. The steam-pressure was only 60 lb. per sq. in. and the blast-pressure only twelve.

The Southwark Foundry & Machine Co., the E. P. Allis Co., the shops of the Tod Engine Co., and, latterly, several others have met the new conditions. Not, however, without some tribulation, for a 100-ft. furnace requires more work to be done than a 90-ft. one; this latter dimension is in my opinion metallurgically more desirable.

The hoist-engines in the majority of cases remain extravagant users of steam. Several plants have introduced electricity to operate the hoist.

In a few plants happily designed, where the height of the furnace is not over 90 ft., there is a surplus of steam obtainable from the furnace-gas after supplying the power-demands and the stove-demands. These plants sell the surplus steam to the adjacent mill. In many other plants the increased blast-pressure resulting from the excessive height of the furnaces or other conditions have nullified the steam-economies resulting from the improved machinery.

In some instances it has been deemed advisable to use the surplus gas to attain a higher temperature of blast (with the view of having a lower fuel-consumption), rather than to sell it to the mill.

*Hot-Blast Stoves.* — In hot-blast stoves, the bottom-rings are now made of such a height that the riveting on of door-frames, ports and branches is done without crossing a seam. These plates are also made very much heavier than formerly because of the higher blast-pressure now used. Stoves of the central combustion-chamber type seem to be gaining in popularity, and brick specially shaped for the checker-work continues to be extensively used.

*Refractory Brick.* — The brick manufacturer has been fully abreast with the requirements, and supplies a cheap brick for the ladle-lining, and a brick free from iron suitable to withstand abrasion for the furnace top, and one free from alkalies and

bases for use with high heats. Prior to the year 1890 a blast-furnace campaign lasted from 18 to 30 months, now it exceeds eight years, and several furnaces have produced more than a million tons of pig iron with one lining, which has reduced the relining charges per ton of iron produced from 50 cents to less than 15 cents.

*Shields.* — A number of shields and protectors have been devised to protect the lining of the upper part of the furnaces from the abrasions of the stock rolling off the bell against the top walls. Of these that I have seen, the best is a suspended sheet of heavy rolled steel, which was introduced by Mr. Firmstone at one of his plants. As used by him, an annular opening extending completely around the furnace top was obtained for a gas outlet.

*Water-Cooling.* — At many plants having a small supply of water, a wooden waterfall is used for the purpose of cooling the condensing water for repeated use.

*By-Products.* — There has been a rapid growth in the use of slag-cement which is placed on the market under the name of " Puzzolini," a name derived from the natural cement rock of Italy. Slag-cement is used as a substitute for Rosendale cement for purposes not requiring the highest degree of reliability. Among other places, it is manufactured extensively in Chicago, Ill., Youngstown, Ohio, and at Sparrow's Point, Md. The process of manufacturing slag-cement has been frequently described, and is being so improved that its consumption will probably increase.

In charcoal manufacture ammonium acetate and wood alcohol are obtained as valuable by-products, and the by-product coke-ovens yield ammonia, tar and gas. Each of these subjects is worthy of an individual monograph, especially the by-product coke-oven, with its promised economies, both in fixed carbon, yield and labor.

*Flue-Dirt.* — The loss of flue-dirt, in the treatment of mixtures containing a high percentage of Mesabi ore, has suggested the use of gas-washers and briquetting-machines. The Steece and the Roberts washers are those in most general use. The Henry S. Mould briquetting-machine has been introduced at several plants to recover the ore that has been blown over from the furnace. The loss through flue-dirt can unquestionably be

lessened by the study of the conditions outlined in my recent paper in our "Transactions," "Flue-Dirt and Top-Pressure in Iron Blast-Furnaces."

*Saving of Gas.* — The introduction of a double bell, preventing the issuance of gas during the lowering of the charge, has resulted in a saving of from 10 to 15 per cent of the gas. At several plants using a single bell the average time during which the bell was open exceeded two hours and forty minutes.

*Blast-Furnace Working.* — Impressive as is the metallurgical practice in America, it exhibits inventive ability less than natural resource. We owe more to the regions named after that emissary of peace, Père Marquette, and the tribes he went out to civilize and Christianize (Menominee and Gogebic), than we do to original research. It is true we have the Uehling pyrometer of American origin, which is an instrument of great precision and of great value to the furnace-man. Our records, however, are characterized by bold application rather than new ideas.

Our high furnaces do not reflect great credit on their designers, though in justice it should be said that most furnace-men were not in favor of 100-ft. heights.

I have personally inspected more than sixty furnaces, and I find that the fuel-consumption, other conditions being equal, is lower on furnaces of from 70 to 80 ft. in height than on furnaces exceeding 90 ft. While Dr. Egleston's records do not include any very high or very large furnaces, the best fuel-consumptions he quotes are in furnaces in the neighborhood of 75 ft. in height.

With very irregular ore or fuel and very expensive coke, it is a question whether a very large output per furnace is desirable. A bad cast if small is more easily taken care of by the mixer than a very large cast. The principal reasons, however, why our fuel-economy has not improved (in fact it has gone backward) are as follows: The coke-ovens have been insufficient to meet the increased demand, and in order to increase production, the time of coking was shortened, which has resulted in a poorer quality of fuel. Then again the shortage of cars has caused many furnaces to be repeatedly banked, which has consequently increased the coke-consumption. Many cokes formerly considered too high in ash, and therefore low in carbon, have been put

on the market.　Finally, the furnace mixtures used have been leaner.

The stove heating capacity has not kept pace with the blowing-power, consequently lower temperatures of blast were used, resulting in a higher fuel-consumption.　In several instances it was considered desirable, in view of a brisk market and large profits, to use the furnace-gas for making more blast, rather than to save the coke, by using a high temperature of blast.

Generally speaking, the silicon requirements for Bessemer iron have been lower, depending upon the location of the plant and other conditions.　The average percentage of silicon may be taken at 1.1 per cent in summer and 0.9 per cent in winter. The lowering of silicon demands has been in the furnace-man's favor.　A brisk market also has lessened the severity of the demands of the mill in sulphur.　I think in some quarters there is a greater tolerance of sulphur than existed 10 years ago.　In other quarters the metal must be remelted if it exceeds 0.05 per cent sulphur.

Owing to the improved preparation of raw material, the furnace-man is supposed to be able to keep the sulphur down without the use of manganese, and as high manganese percentages, through the great spluttering they occasion, prevent the forcing of the work in the converter, this element is a greater detriment in iron-ores than it was in the beginning of the past decade.

The increased purchase of ore containing a higher phosphorus-content has accompanied the rapid extension of the basic open-hearth steel process.　It is not unusual upon the shutting-down of the converter on Saturday afternoon, while the metal is being run into the chills or through the pig casting-machine, to put a basic mixture in the furnace, a procedure which is especially desirable if the furnace capacity of direct-process metal is sufficient for the converter capacity and need not be supplemented by remelting the Sunday's product in a cupola-furnace.　The direct process, with the great advantages afforded by the closing-down of the cupolas, has been greatly extended, and molten metal in Pittsburg and Cleveland is carried in 20-ton cars for more than a distance of five miles.

The use of multiple tuyères has not always been attended with satisfaction, and a more conservative estimate of their benefits now prevails.

The drying of furnaces preparatory to " blowing-in " is now much shorter in time than was the practice a decade ago, many thinking a week quite sufficient. During the blowing-in period the burden is now increased more rapidly, and the quantity of wood used is very much less than formerly. I know a very successful operator who uses no more than a cart-load of wood for blowing-in a large furnace, and a few who light the furnaces in starting by means of red-hot iron-bars introduced through the tuyères, while the blast is on. Red-hot charcoal also is satisfactorily used by some who blow it through the tuyères during the starting of the blowing-in. The hot-blast stoves can now be heated higher previous to starting than was formerly practicable, owing to the use of natural gas or the universal gas-main.

A saner treatment of the tap-hole now prevails, due to the recognition that an exceptionally large product for a single day means little, and as a consequence the last portion of iron in the crucible is not drawn out by long prolonged blowing at the tap-hole. The blowing at the tap-hole leads to break-outs, on account of the heating up of the furnace-front.

The blowing away of furnace bell-and-hopper by slips, which frequently occurred after the introduction of Mesabi ore, are now unusual. This usually disastrous irregularity was then attributed to a so-called dust-explosion, but I think this assumption is wrong, and the irregular working, even with high percentages of Mesabi ore in the charge, can be obviated.

The proportion of Mesabi ore used in the ore-mixture has, in exactly a decade, increased from 25 to 100 per cent, a furnace in Pittsburg having been blown-in recently with the ore-mixture composed entirely of Mesabi ore.

While the ingenuity of American metallurgists savors less of the lamp than that of European engineers, still in the recognition that fine ores are quickly reduced in the furnace (analogous to the manner in which salt enters more readily into a solution if the more finely divided, and its corollary, that a finely divided material must be given a large volume of solvent in order to dissolve it rapidly) ; and by applying this principle American engineers have acted with great promptness and received enormous returns.

The introduction of gas-engines at the Buffalo plant of the Lackawanna Steel Co. has marked an important epoch in blast-

furnace practice. By eliminating boilers, and thus combining the duties of boiler and blowing-engine, economies are promised amounting to 20 per cent.

Through the courtesy of Mr. Wehrum, formerly the general manager of the Lackawanna Steel Co., the following data on the company's gas-engines have been contributed:

"The distribution of the units of horse power of blast-furnace gas-engines installed in Europe prior to February, 1902, was:— England, 600; Italy, 1,800; Russia, 2,230; Austria, 2,840; France, 7,400; Belgium, 7,600; Luxemburg, 15,400; and Germany, 44,665; making a total of 82,535 horse-power.

Blast-furnace gas in gas-motors is 37 per cent higher in efficiency than that used to produce steam, and I estimate that the engines introduced at the plant of the Lackawanna Steel Co. under my administration shows an economy of fully 300 per cent more than that of the single-condensing steam blowing-engines, which is equivalent to a saving of $12.50 per horse power per year, by the introduction of blast-furnace gas-motors. Gas-engines are now installed and in operation at the Buffalo plant of the company to the extent of some 5,100 horse power."

The above-mentioned quantity of horse power (82,535) has since been increased to 297,050, which is distributed among the various gas-engine makers as shown in Table I.*

TABLE I. — *Blast-Furnace Gas-Engines (Exceeding 200 H. P.) Completed or in Course of Construction Oct. 31, 1903*

| Name of Maker | Deutz | Koerting | Nuernberg | Oechelheuser | Cockerill | Total |
|---|---|---|---|---|---|---|
| Number of engines... | 123 | 70 | 57 | 41 | 116 | 407 |
| Total horse power... | 49,225 | 83,475 | 61,350 | 27,400 | 75,600 | 297,050 |
| Average horse power. | 400 | 1,192 | 1,075 | 667 | 652 | 730 |

For those who wish to study this subject further, I refer them to the interesting brochure published by Mr. Wehrum.† Considering the fact that about two-thirds of the gases are now used for the production of power and one-third for heating the stoves, the subject is well worthy of study.

* "Iron Age," January 14, 1904.

† Studies of Blast-Furnace Gas and Its Most Economical Use, Scranton, 1900.

Mr. Uehling* makes a statement, that for each ton of pig iron produced per hour there will be available 800 h.p. for sale or for use in connection with the rolling-mills connected with the blast-furnace plant, and Mr. F. duP. Thompson, who assisted Mr. Wehrum at the Lackawanna Steel Co.'s plant, is of the opinion that 500 h.p. per ton of pig iron produced per hour would more nearly approach practical working.

The blast-furnace has always been regarded as representing a high degree of efficiency. In the direct process, the heat contained in the molten iron has been saved, and doubtless ere long the heat of the molten slag also will be utilized. But it is in the line of using waste-gases that our signal economies have been scored. First, in using it under the boilers, then, in using it under the stoves, then, in sealing the top of the blast-furnace with a double bell, then, in selling the excess waste-gas to the mill in the form of steam, and now, after continuously demanding more from it, we hope to receive more by the introduction of gas-engines.

In the Metallurgical Congress, which I suppose will form a part of the Louisiana Purchase Centenary, it will be appropriate to record the progress of that plant of unrivaled natural resources, *viz.*, the Colorado Fuel and Iron Company, situated in what was then the great American Desert, and what is now one of the greatest coal-fields and ore-deposits of the world.

Although our coke-consumption remains between 1,750 and 2,100 lb. per ton of metal produced, our daily output per furnace has jumped from 350 to 500 tons and more in a decade, and the total yearly output of pig iron, according to Mr. Swank, has grown from about 8,000,000 tons to 18,009,252, tons in 1903. This rapid increase in the production can be understood when it is known that one 500-ton furnace has been erected and produced iron within one year and one day after the pick was first driven into the ground.

In the iron world it has been proven that high wages need not mean increased cost of production. The region between the Great Lakes and the Connellsville coal-field is still regarded as being a section where the most advantages are found, possessing easy access to high-grade cokes, the best ores, the most skilled and ambitious labor, the greatest mechanical ingenuity and the best markets. Colorado and Alabama also hold strong positions.

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*"Stevens' Institute Indicator," January, 1903.

While the decade has recorded the abandonment of many plants economically unfit, it has been a period of great activity in building new plants in the localities above mentioned as well as in Canada and Mexico. The tendency has been towards fewer units and larger units, towards a keener appreciation of the reduction in cost resulting from using a large output as a divisor, particularly with reference to the reduction of the cost of management and fixed charges.

A series of observations by barometer and hygrometer emphasizes the disadvantages of high humidity, and have led in a few instances where there were hot, moist engine-rooms to the supply of air from outside the building by means of especially constructed pipes. This also is a line of investigation receiving the attention of some of our foremost furnace managers.

I fully realize that many names entitled to special mention for having taken a prominent part in the astounding progress of our industry have been omitted from this paper, and I can only trust that no one will feel that a discourtesy has been intended. In a State whose motto, "Manly in deed and soft in speech," is so eminently urbane as Maryland, such a course would be out of place. I cannot, however, close this brief record without the mention of the one whom I think has most clearly discerned the trend of events. — Mr. James Gayley early saw the possibilities of Mesabi ores and the methods of handling them, as he also saw the advantages of a low bosh and a large hearth. Both in justice and with a sense of personal loyalty, I feel that the name of Mr. James Gayley should be placed permanently among those who have contributed so much to the splendid development of the blast-furnace practice during recent years.

A worthy review of the blast-furnace advance cannot be compressed into the short limits of this article, nor had I sufficient time to treat it other than I have done. This paper has been written in the hope that it might awaken the members to how few papers on blast-furnace practice there have been published during the past decade. Our " Transactions " were formerly crowded with such records. Possibly our iron men translate Maryland's motto to mean, " Deeds are masculine and words are feminine," and have rested content with the work that they have done.

## DIRECT-METAL AND CUPOLA-METAL IRON CASTINGS*

By THOMAS D. WEST

Sharpsville, Pennsylvania

A SHORT time ago, I had occasion to cast plates 1 in. in thickness, with direct metal containing Si, 0.51; S, 0.045; Mn, 0.75; and P, 0.094 per cent. Much to my astonishment I found that there was no trouble in planing them, whereas if cupola metal of like composition had been used, the planing would have been a difficult operation. In view of the interest taken at the present time in the subject of using direct metal for foundry purposes, a few remarks on my observations, while handling this metal in daily routine, may not be amiss, and may create discussion.

I have often noticed a greater fluidity or life in furnace metal when compared with the cupola product. Iron can be seen flowing down the furnace-runners from 50 to 100 ft. before reaching the last pig in very satisfactory shape, while cupola metal might solidify before it had reached one-half the distance. I have seen Bessemer iron in a 30-ton ladle held for nearly an hour and a half during repairs to a crane; and after skimming off the coke dust, it had to be cooled off considerably before being cast. As a general proposition it is known that the comparatively lower sulphur-content and the higher temperature of direct metal over the same iron remelted in the cupola has much to do with its greater life, yet there are some problems connected with this phenomenon which would seem to call for further study. For instance, furnace metal containing more than one per cent silicon holds carbon, which is separated as "kish." This separation does not take place to any great degree while the metal is very hot, but during its gradual cooling, at times, the kish is given off

in such large quantities as to cover the ground for an area of from 20 to 30 feet around the ladle.

Perhaps this throwing out of the excess carbon then makes the life of the metal shorter thereafter. It would be well to ascertain the carbon-content of a ladle of iron during the stages of the cooling process, and thus determine the effect of the carbon reduction more accurately.

In making "direct metal" castings the separation of kish becomes a nuisance, although it is more generally confined to the higher silicon metals. The higher carbon undoubtedly has much to do with keeping metal with the lower quantities of silicon softer, than if it were a cupola product of like composition excepting the total carbon-content. Perhaps some of our furnace friends can throw light on this interesting matter.

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## STOCK DISTRIBUTION AND ITS RELATION TO THE LIFE OF A BLAST-FURNACE LINING*

By DAVID BAKER
Formerly General Manager Dominion Iron and Steel Co., Sydney, Nova Scotia
Philadelphia, Pennsylvania



WHEN the skip-hoist was first tried as a means of filling the blast-furnace it made a great many enemies and very few friends among furnace managers. This state of affairs continued until the Duquesne furnaces were built, which demonstrated not only the possibilities of a furnace-stack in the way of production, but also the ability of the skip-hoist to charge the materials necessary to produce the large tonnage obtained. Every furnace manager, who has operated stacks fitted with the vertical hoist and the hand-barrow system of filling, remembers that the momentous ques-

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tion about the furnace, particularly during a good run, was: "Are you keeping her full?" and many a good run has been spoiled by the furnace "getting away from the men."

With the new birth of the skip-hoist this trouble was eliminated, but alas! other and more important difficulties arose. The distribution of the stock, the importance of which is never learned until many different ores and fuels have been tried, demanded closer attention. With all the defects of the hand-barrow system, the distribution — when the top fillers were conscientious in carrying out the filling scheme arranged after thoughtful consideration by the manager — was above criticism. It is said that the modern skip-hoist, equipped with an elliptical hopper and receiving cylinder, and discharging over a small bell into the main hopper, will give just as good results as those obtained with hand-barrow charging, but I cannot agree with this statement. I grant that, under very favorable conditions, the mechanical furnace-top will do apparently as well as the hand system of charging, but under unfavorable conditions it fails. It is the unfavorable case that is all important, for that frequently means the success or failure of the business concerned.

I am now speaking from my own experience. Possibly there is in the market to-day a mechanical top-charger that will give as good distribution as that obtained by the hand-barrow system, but the low fuel-consumption obtained by the furnaces equipped with the old system has never, to my knowledge, been equalled by those with the new. Can any one point to such a record by a new plant as that reached by Furnace No. 6 of the Illinois Steel Company, which showed for a year a fuel-consumption of 1,581 pounds of coke per ton of pig iron produced?

I believe the reason for this lies in the great abuse to which coke is subjected in these new plants. I refer to the great number of times the coke is required to drop from one receptacle to another, grinding much of it into dust and breaking the balance into pieces much smaller than those of the original coke freshly drawn from the oven. It is quite common at such plants for the coke to be forked into hopper-cars at the ovens, dropped from these into a deep steel bin at the furnace, drawn into the larry-car, dumped into the skip, thence into the top receiving-hopper, from which it drops on to the main bell, and is finally discharged into the furnace. Other modern plants avoid one

dump by chuteing the coke direct from the bins to the skip-cars. On the face of it this seems to avoid one handling and to save a great deal of breakage, but usually these bins are so much deeper than those in connection with the larry that the breakage is nearly as great.

By this mechanical system the coke is dropped from six to seven times as compared with three or four times by the hand-
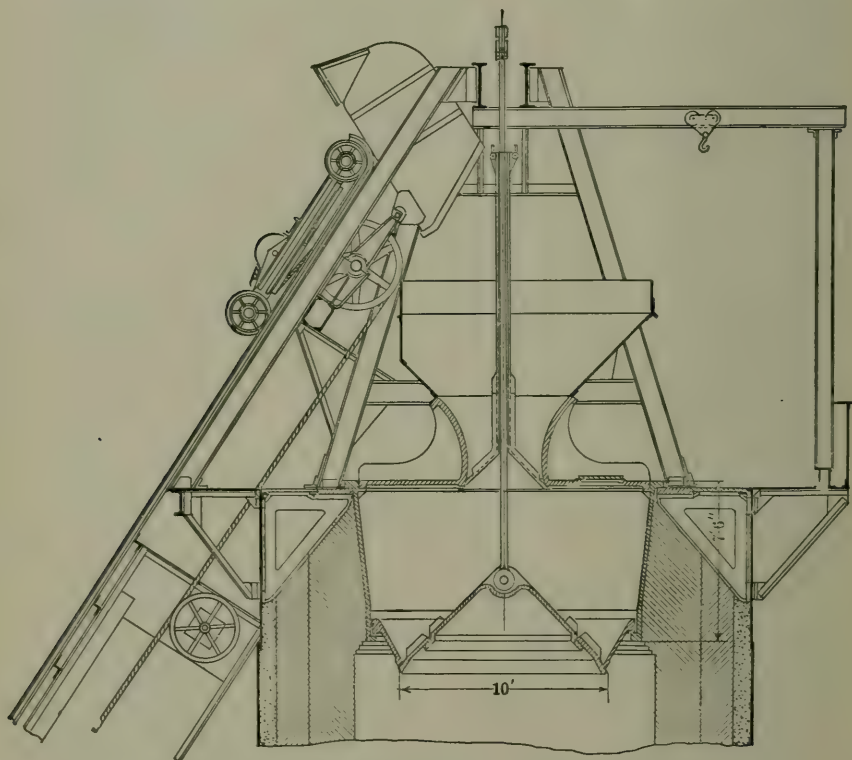


Fig. 1.   Top of Furnace No. 1.   First Campaign.

barrow system, and one of these (from the barrow into the furnace-hopper) can hardly be called a drop, the breakage resulting therefrom being so slight.

Many of my readers have seen what, ten years ago, might have been called a modern plant, equipped with hand-barrows which take the coke direct from box-cars into barrows; in this system the coke receives practically only one drop that is likely

to cause any breakage, *i.e.*, when it is discharged from the bell into the furnace.

This careful handling of the coke is of the utmost importance, and when the coke is of a soft or friable nature, it may mean the difference between the success and the failure of the blast-furnace operation.

The baleful results of the breakage by the repeated handlings of coke in the modern furnace plant equipped with the usual mechanical charger, as well as the necessity of obtaining good distribution of the stock, were demonstrated very clearly at the plant of the Dominion Iron & Steel Company, at Sydney, Nova Scotia.

The coke, made in the Otto-Hoffman by-product ovens about 1.5 miles from the furnace plant, is delivered to the furnaces in hopper-cars each of 20 tons capacity, and is dumped from them into large coke-bins at the foot of the skip-hoist; thence it is drawn direct into the skip-bucket.

The hoist is a double-skip arrangement, and the top charging device, shown in Fig. 1, consists of a circular hopper, having the discharge controlled by a small bell.

The coke used at this plant is made from the Dominion Coal Company's coal, and is very friable and quite soft.

The first furnace was blown-in on February 4, 1901, very successfully, and everything worked smoothly for a few weeks; but, at the end of this period, the furnace began to hang and slip and burn tuyères, sometimes cutting at a slip every tuyère in the furnace. The tuyères failed in nearly every case on the lower side of the nose, showing that they must have been flooded by cinder and iron when the slip occurred. The destruction was so rapid that, in some cases, the tuyères exploded, blowing down the " blow-pipes " and the " pen stocks," causing a panic among the furnace men and not adding to the comfort of the furnace manager.

An analysis of the flue-dirt gave the following results, which show that most of it was coke: Loss on ignition, 52.87; $SiO_2$, 8.60; $Fe_2O_3$, 16.35; $Al_2O_3$, 6.56; CaO, 5.51; and MgO, 3.46 per cent.

The coke in the bins was very dirty and badly broken, and it was apparent that the coke in the hearth of the furnace was so finely divided that the slag found great difficulty in settling

through the mass, particularly during a slip; hence, the flooding of the tuyères with cinder and iron, and their consequent destruction.

In fact, it was only after long blowing at the cinder-notch and repeated checkings of the blast that the tuyères could be dried sufficiently to take off the blast without filling the blow-pipes.

The first effort made to reduce the tuyère destruction was the increase of the feed-water pressure by changing from the regular tank-service of salt water at 20 lb. to the fresh-water main at 40 lb. per sq. in. This made only a slight improvement.

Next was the steady increase of the number of engine revolutions, until an average volume of 36,000 cu. ft. per minute, measured by piston displacement, was forced through the tuyères. After this change the slipping was less frequent, the output greater and, at the same time, no more tuyères were lost.

Finally, silica rock was introduced in the charge, which had a marked effect, making the slag very fluid, reducing the burning out of the tuyères materially and increasing the output greatly. The best results were obtained by the addition of 200 lb. of quartz-gravel for each ton of ore charged, changing the slag analysis from 31.54 to 34.32 $SiO_2$, and from 15.2 to 12.76 per cent $Al_2O_3$. At that time dolomite was used as a flux.

The ore obtained from Wabana, Bell Island, Conception Bay, Newfoundland, is a uniform, dense, red hematite, which has been split up *in situ* by cleavage planes into lumps of rhomboid shape, having a similar appearance to broken red brick.

The ore is practically free from fines and is of the following average analysis: Fe, 51.43; $SiO_2$, 14.03; $Al_2O_3$, 4.57; MgO, 0.52; CaO, 2.23; Mn, 0.15; P, 0.805; S, 0.038; and $TiO_2$, 0.45 per cent.

The high percentage of alumina in the ore seems to render the slag viscous, and is only corrected by the addition of silica, the best results being obtained when the slag does not exceed 13 per cent alumina. Probably the titanic acid also adds considerably to the infusibility.

Notwithstanding all the changes noted above, which lessened the destruction of the tuyères, there was still room for much improvement. Screens were placed in the chutes from the coke-bins to the skip-buckets, which eliminated 4 per cent of fine coke-braize.
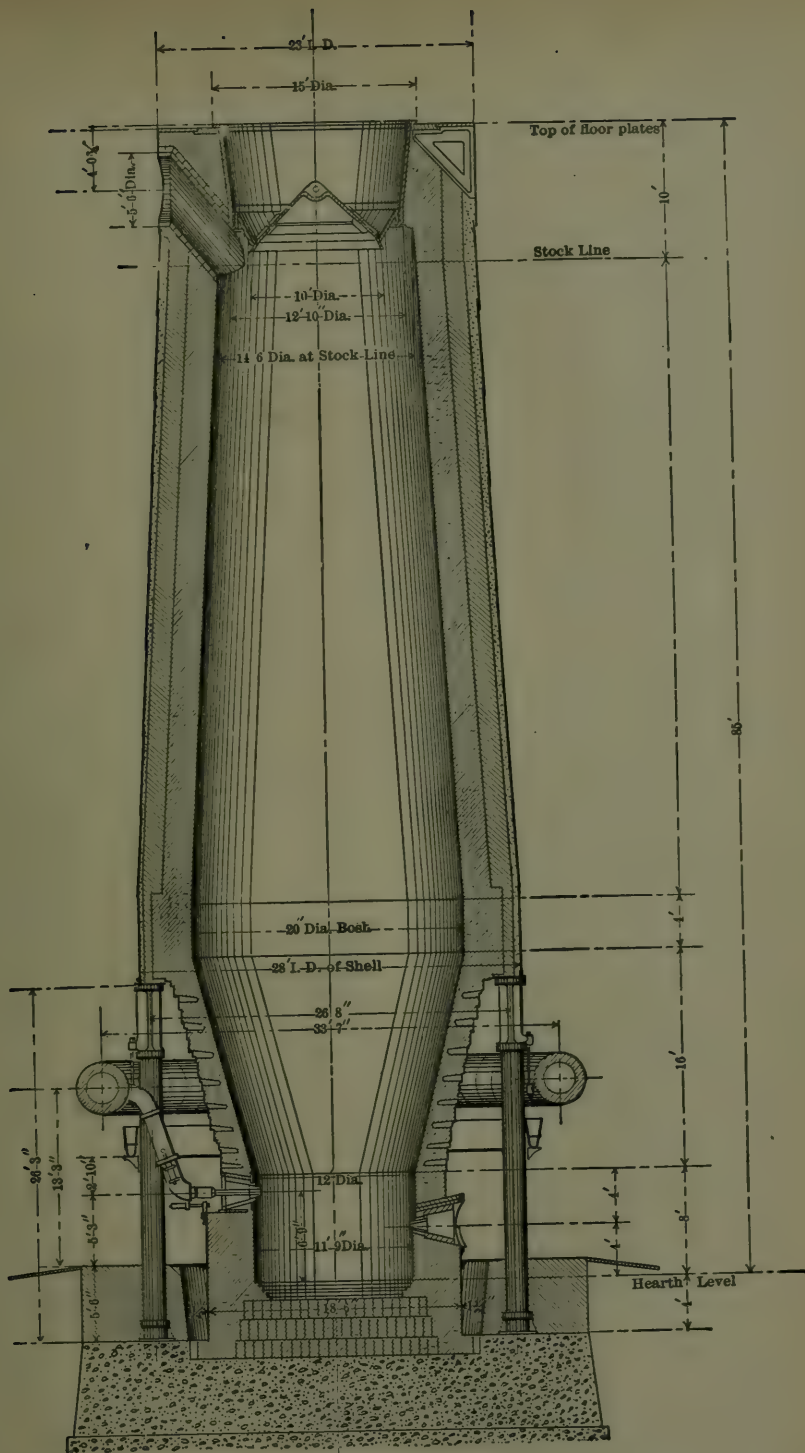
Fig. 2.  Sectional View of Furnace No. 1.  First Lining.

These changes had hardly been accomplished when the shell of the first furnace began to show an unusual temperature about 20 ft. from the top of the bosh and opposite to the skip-way. The furnace had been in blast only six months, and the bricks, made by Harbison & Walker, of Pittsburg, Pa., were held responsible for this rapid failing of the lining. It was stated by those present when these linings arrived that the bricks had not been properly housed, and had been subjected to freezing after being wet. Fig. 2 shows the first lining, in which the bricks used in backing up the in-wall were of second quality Scotch make. The burned lines of this furnace, Fig. 3, shows that the failure of the in-wall was confined to the side opposite the skip-way.

The second furnace started, No. 2, five months after the blow-in, developed the same weakness in identically the same place.

From the first I doubted that the bricks were wholly responsible for these failures; and when the third furnace, after a most favorable start, with all the conditions normal, developed a hot spot within three weeks after blow-in, and cut through nearly 5 ft. of fire-brick in exactly the same location, I was convinced that the true cause of the trouble should be sought in another quarter. The condition of the coke charged and the distribution of the charge had been carefully studied for some time, and it became evident that they had some connection with the irregular wear of the furnace in-walls.

When the first lining failed, a model furnace was prepared with a complete top-charging arrangement, the shell being of glass strips fastened to narrow wooden strips, so that the descent of the charges could be observed. The material was drawn from the bottom so as to lower the stock in the same way as the blast-furnace charge is moved by the combustion of the coke in the hearth. At the same time a careful study was made of the actual filling at the furnaces in operation.

The result of this observation showed that the furnace-hopper was filled in the manner illustrated in Fig. 4; the finer portion of the charge remained under the dumping point of the skip, while the coarser portion of each material rolled to the other and the same side of the furnace where the lining had failed in every case.

Section A-B

Stock Line

Lines Indicate Section through E-W
Lines Indicate Section through N-S
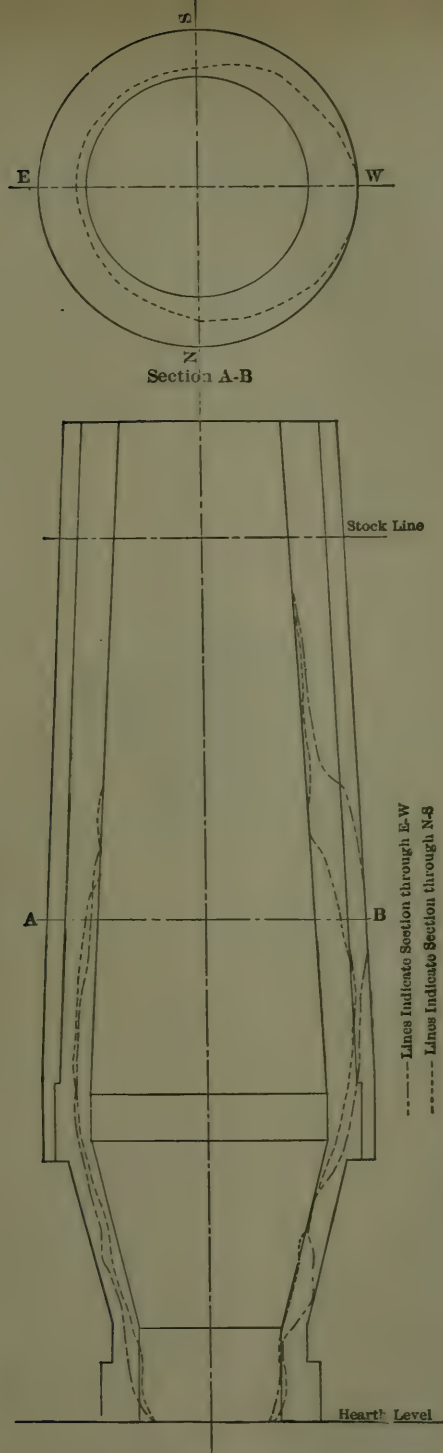
A —————————————— B

Hearth Level

Fig. 3. "Burned" Lines of Furnace No. 1.  First Lining.

The furnace, therefore, had on one side the best coke and all lump ore and flux, while on the other side was the coke-dirt and fine coke with the finer portion of the ore and flux, which latter material had been crushed at the quarry to pass through a 4-in. ring. As a result of this condition the furnace worked
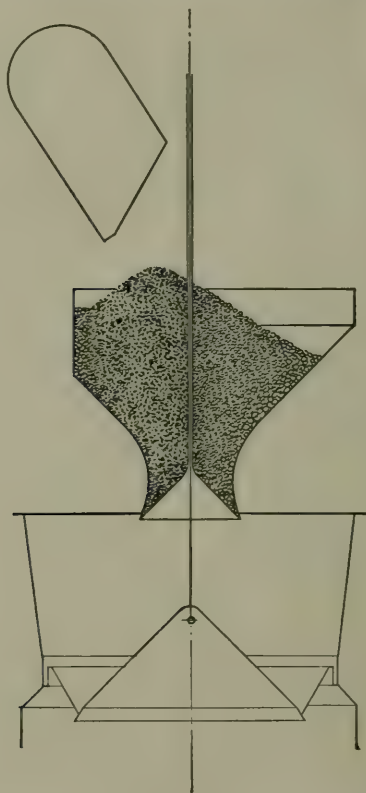


Fig. 4. The Distribution of Ore in the Stock-Chute of Furnace No. 1. During the First Campaign.

faster and hotter on the side having the most lumps; in fact, it was " channeling " in that direction. Had the charge been of regular Lake Superior ore, with about 10 per cent lump mate-rial, and Connellsville coke, probably no such separation would have been noticed, for there would have been enough fine ore to have made the charge practically of the same penetrability to the upward-moving gases, and very much less breakage of
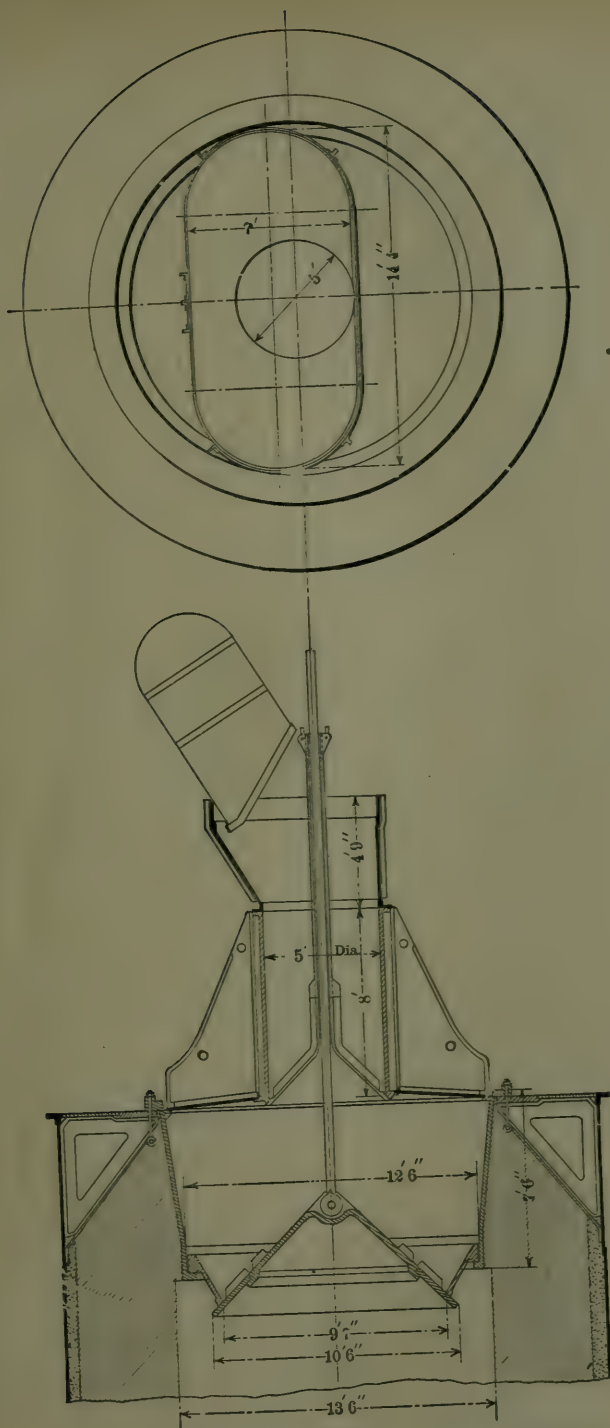
Fig. 5.—Top of Furnace No. 2.    Second Campaign.

fuel, so that in efficiency the whole charge would have been more nearly the same.

In order to correct these defects of distribution, a top for Furnace No. 2 was designed, as shown in Fig. 5.

In this new furnace-top an elliptical hopper replaced the old circular one, the idea being to prevent the sizing of the material by discharging this elliptical hopper into a cylinder closed by a bell. The head-frames of the top were so low that the cylinder could not be made as long as was desired, and it did not have quite the capacity of two full skips. Four months after the " blow-in " this furnace developed a hot spot, on the side opposite from the others, which apparently showed that the sizing had been reversed, but not corrected.

The second attempt to correct the distribution without entirely removing the head-frames and changing the angle of the skip-way is shown in Fig. 6.

In order to make room in the cylinder for two full ship-loads of coke, the diameter was increased to 6 ft., and the lower part of the elliptical hopper was extended into the cylinder, thus narrowing the opening to 3.5 ft., so as to throw all of the material to the center of this cylinder and in the sizing, which must inevitably take place, to leave the fines in the center and the lumps next to the shell of the cylinder. This furnace has now been in blast 18 months and has not shown any unusual heating in the shell.

The breakage of the coke continues and cannot be remedied with such a filling system, but enough has been done to show that with well coked, washed coal a fairly uniform furnace practice can be maintained with only the normal destruction of tuyères. Unquestionably, the excessive breakage of the fuel very materially lowers its practical calorific efficiency in the blast-furnace. This efficiency is in inverse proportion to the breakage, for, other conditions being equal, the amount of carbon absorbed by the hot $CO_2$ of the gases is in proportion to the surface exposed. This means that, other things being equal, the fuel-consumption in a blast-furnace per ton of pig iron produced is directly proportional to the breakage the coke receives between the oven and the hearth of the furnace. Therefore, in laying out new works it is of the utmost importance to have the blast-furnaces and coke-ovens studied together from this stand-
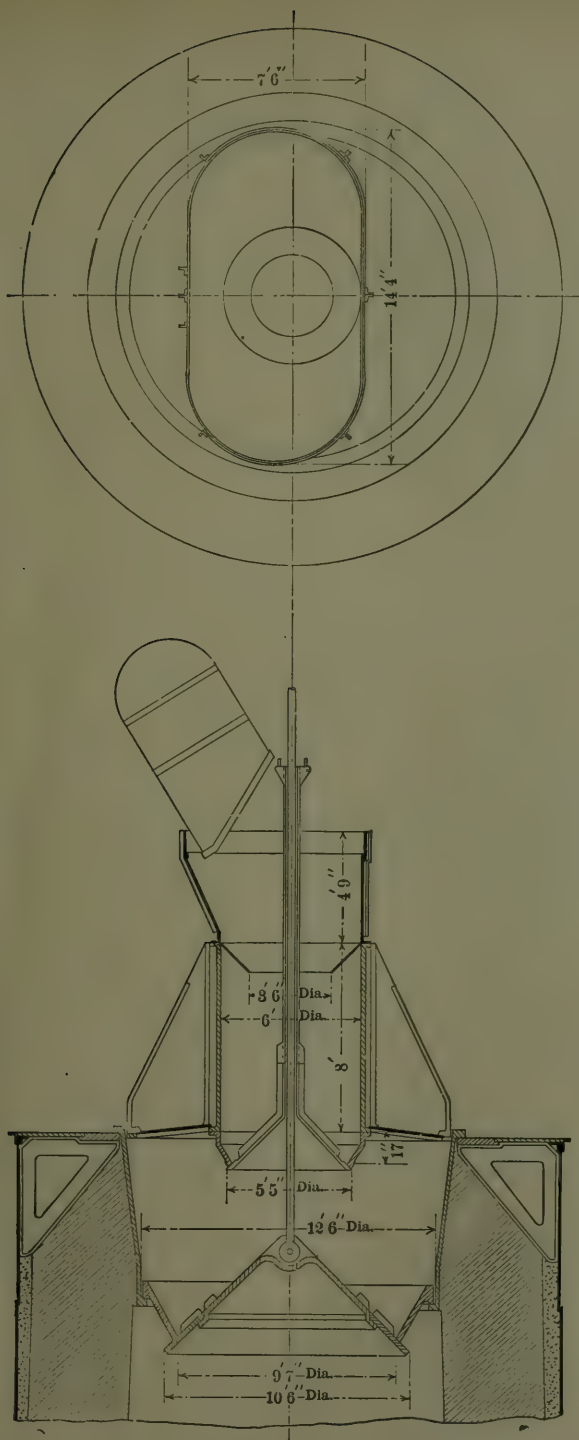
Fig. 6. Top of Furnace No. 3. Second Campaign.

point, in order to put the coke into the furnaces with the mini-
mum amount of handling.  This amount may be reduced with
the right design to only two drops.

In recapitulation, this experience demonstrates that greater
care is needed to distribute well an ore that is all lumps, partic-
ularly when smelted with soft coke that is subjected to the
abuse of the repeated handlings incident to the modern filling
and charging device.  Whether the labor saved by such filling
arrangements compensates for the loss due to impaired efficiency
of the fuel resulting from such abuse, is a question left for others
to solve.

# REVIEW OF THE IRON AND STEEL MARKET

The very gradual improvement in the iron and steel trade noted in our reports since the first of the year has had a remarkable gain in strength during the past month. Transactions are heavier in pig iron and in nearly all lines of finished steel, while in a number of instances prices have advanced.

It is well understood that the American iron trade nearly always moves in a grand swing; when a slight downward tendency is once manifested, it gains headway, while the appearance of a slight revival starts a general movement in the opposite direction. All through 1903 conditions had been growing worse and worse until they culminated in a situation where production was far below the normal even for bad times, and no change was possible except one for the better. This change has been in progress, and has gathered momentum each month this year. How long it will last no one can say, but it is hardly probable that it will be continued throughout the year. There are likely to be many setbacks in the rehabilitation of the trade after the exciting prosperity of the past four or five years, the most prosperous period the trade has ever seen.

About the first of March the United States Steel Corporation closed a transaction for the purchase of Bessemer pig iron involving about 130,000 tons, a portion of which, however, was merely taken under option. This was done for three reasons: (1) because the corporation really needed some prompt iron; (2) for its influence on the ore situation, it appearing almost impossible to patch up an agreement among the Lake Superior ore producers for the coming season; (3) for its influence on the general iron and steel market. The iron was taken at $13, f.o.b. valley furnace, which was from 25 to 50 cents above the then market.

This transaction, aided by a generally better feeling in most finished steel lines, has created an improved sentiment in all

quarters. Transactions have been larger, and prices in many cases have been advanced slightly.

The United States Steel Corporation has withdrawn its low price of 74 shillings, delivered Swansea, on sheet bars. It was supposed that on account of the pig iron purchase it would be necessary to " dump " that much more steel abroad. If so, the withdrawal is simply temporary, to allow the market to recover, the Germans being given an opportunity, with their newly formed steel syndicate, to put up their prices. Such a price as 74 shillings was of course an extremely low one, since it meant a trifle under $14, f.o.b. Duquesne, when the actual factory cost of the steel is around $13, while fixed charges including selling expenses, taxes, insurance, bonds and purchase money obligations of subsidiary companies, etc., all coming before money can be earned on the corporation first mortgage bonds, amount to some $5 per ton.

On March 1 the National Tube Company made an advance of one point on all sizes of steel merchant pipe up to and including 6-inch, following a similar advance February 1. These two advances restored the prices ruling until December 29, 1903, when a two-point reduction was made all through the list, except that half-inch pipe was reduced three points. Sizes 7 to 12-inch remain at the two point reduction from the list in force during 1903. The present discounts in per cent off list, carload lots to consumers, are: ⅛ to ⅜-inch, 68; ½, 71; ¾ to 6, 75; 7 to 12, 71. As the list of prices per foot makes the price per pound an average of about 10 cents, a point is equivalent to about $2 per net ton. Galvanized pipe is 10 points less discount than black steel pipe all through. The advances this year were made mainly to protect contracts made with jobbers, thus assuring them a fair profit. Sizes 7 to 12-inch, not sold largely through jobbers, were consequently not advanced.

On March 5 the American Steel & Wire Company promulgated its long expected advance of 5 cents a hundred pounds on all its wire products, making minimum prices, in carload and larger lots to jobbers, $1.80 per 100 lbs. on plain wire and $1.90 per keg on wire nails, both base. The wire trade is in very strong condition.

Another ineffectual effort to settle the Lake Superior ore question for the coming season was made in New York March 7,

the producers adjourning until April 1. The situation is such that the interests of the steel producers mining their own ore and the merchant ore producers, mining ore for the market, are distinctly at variance. The former desire a high price while the latter desire a price low enough to enable them to sell ore. The steel interests desired a price fixed of $4 on old range Bessemer and $3.65 on Mesabi Bessemer, against $4.50 and $4 ruling last season, while the merchant ore interests desired a flat reduction of $1 per ton, later modifying their demand to 70 cents. There is serious danger that the whole situation will be thrown open, whereupon ore will be sold in the open market in competition, and prices will decline to something like the level which prevailed in 1899 and previous years, when ore sold at from $1 to $2 below the prices which have prevailed in subsequent years.

*Pig Iron.* — There has been a decided improvement in both demand and prices since the latter part of February, when a low point of close to $9 was made on No. 2 foundry at Birmingham, and $7.80 to $7.90 on forge at Birmingham, No. 2 foundry selling in northern markets at about $12 at Ohio furnace. Prices now are about as follows: At Birmingham — No. 2 foundry, $9.75; forge, $8.25 to $8.50. At Pittsburg: Bessemer, $14.10 to $14.35; No. 2 foundry, $14.00 to $14.25; forge, $13.25 to $13.50. At Mahoning or Shenango valley furnace: basic, $13.00; Bessemer, $13.25 to $13.50; No. 2 foundry, $13.25 to $13.40. At Chicago: local No. 2 foundry, $13.75 to 14.00. At Philadelphia: No. 2X foundry, $14.75 to $15.00; No. 2 plain, $14.25 to $14.50.

*Billets.* — There is considerably more business in billets, association prices being well maintained at $23, delivered Pittsburg, Wheeling, valleys, Johnstown, Ashland and Lorain; Philadelphia and Baltimore, $24.25; Chicago, $24; Cleveland, $23.50; New York, $24.75; with advances as last quoted for carbons and other sections.

*Merchant Bars.* — The market is very strong, mills being in receipt of good orders and contracts for both steel and iron bars. The Merchant Steel Bar Association March 14 advanced Bessemer steel bars one dollar a ton, to 1.35c., base, f. o. b. Pittsburg in carload or larger lots, leaving open-hearth bars unchanged at 1.40c., base. The consequent decrease of a dollar a ton in the spread between Bessemer and open-hearth steel bars is in consonance with the fact that Bessemer and open-hearth billets are now

selling at the same price, in distinction from the differential which formerly prevailed. Common iron bars are much stronger, and the market generally is quoted on the basis of 1.35c., base, f. o. b. Pittsburg, plus freight, making the delivered price Chicago 1.50c. For strictly Pittsburg delivery, however, most mills are quoting 1.45c.

*Plates.* — The plate market is stronger and more active. Prices are unchanged from those previously reported, based on 1.60c for tank quality. Shapes are also in better demand, a considerable quantity of structural work being in hand. Quotations are unchanged.

*Sheets.* — The association of independent sheet manufacturers has about gone to pieces so far as any market regulation is concerned, and prices are probably being shaded somewhat in extreme cases, the regular market, however, being 2.30c. on black and 3.30c. on galvanized, No. 28 gauge, in carload lots.

A. LEDEBUR

PROFESSOR OF METALLURGY AT THE ROYAL MINING SCHOOL
OF FREIBERG

# The Iron and Steel Magazine

## AN ANNOUNCEMENT

THE readers of this magazine will doubtless realize that a publication so costly to issue cannot be self-supporting unless it receives a certain amount of patronage from the advertising public. When the publishers, because of this necessity, attempted to secure some advertising matter they soon discovered that the title of the magazine was a serious handicap to their success. Would-be advertisers inferred from the terms " Metallurgist " and " Metallographist," that the publication was of too technical a character to be of much value to them as an advertising medium. This will explain the change of title which begins with the present issue. The words " Metallurgist " and " Metallographist " had to be sacrificed on the commercial altar.

The publishers feel confident that their readers will not only fully appreciate this necessity, but that they will approve of the change, for they will realize that the very existence of the magazine depends upon the publishers being able to secure a small amount at least of advertising matter, and that the original title appeared to be a serious obstacle to their success in this direction.

The publishers desire to emphatically state, however, that this altered title does not in the least imply a change of policy in the editorial conduct of the magazine. It will be their constant effort to more than fulfil the promise made in their first issue, and to strive unceasingly to make their magazine the worthy representative periodical of the Iron and Steel Industry.

# SORBITIC STEEL*

By H. C. BOYNTON

Cambridge, Massachusetts

ABOUT a year ago in the Transactions of the American Institute of Mining Engineers the author published jointly with Professor Albert Sauveur, a paper entitled " Note on the Influence of the Rate of Cooling upon the Structure of Steel." In that paper the authors made the point that steels containing less than 0.80 per cent carbon, samples heated to 1000° C. or higher and cooled in the furnace possess a structure made up of true pearlite and ferrite (see Fig. 1), while samples of the same steel heated to the same temperature on being cooled in the air, exhibit a structure made up of sorbite and ferrite (see Fig. 2). This
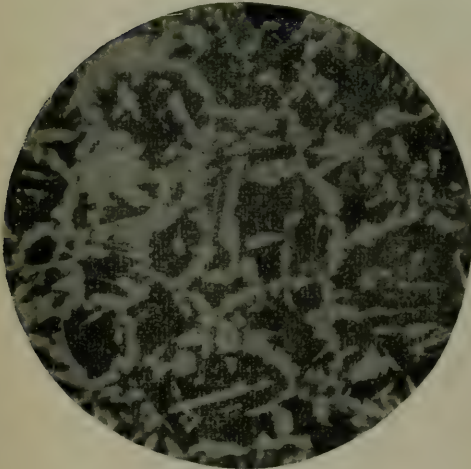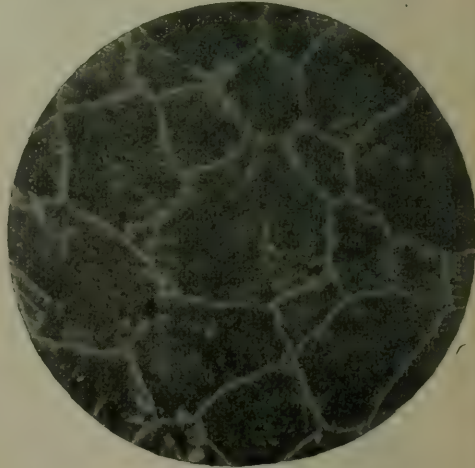


Fig. 1.  Ferrite and Pearlite.
100 diameters.

Fig. 2.  Ferrite and Sorbite.
100 diameters.

sorbite was defined as simply a " dilute or ferrous pearlite," the reason for its formation being that the rapid cooling in the air, through the critical point, did not allow sufficient time for the excess ferrite (that above the eutectic ratio, 0.80 per cent) to separate out from the solid solution, martensite; leaving, on cooling below the critical point, sorbite, a constituent of variable iron content containing more ferrite than is necessary for the eutectic ratio, and consequently a smaller proportion of carbon than pearlite.

It was shown in this same paper that a steel containing a large amount of sorbite (0.55 per cent carbon in the case cited) possessed a higher tensile strength and elastic limit than the furnace-cooled sample, but on the other hand less ductility (see Diagram 1).

*Diagram I*

| Treatment of Sample | Character of Dark Constituent | Elastic Limit Lbs. per Sq. In. | Tensile Strength Lbs. per Sq. In. | Elongation Per Cent in 8 Inches | Reduction of Area Per Cent |
|---|---|---|---|---|---|
| Heated to 1150° C. and cooled with furnace . | Pearlite | 39,901 | 81,162 | 17 | 27.61 |
| Heated to 1150° C. and cooled in air . . . . | Sorbite | 53,260 | 99,979 | 12 | 20.55 |

Other metallurgists have been experimenting along this line, and in view of the fact that steels which are made up largely of sorbite have a greater tenacity and elastic limit than those in which the dark constituent is true pearlite, these metallurgists have been endeavoring and have succeeded in producing steel rails which are made up largely of sorbite. These rails they have called " sorbitic steel rails " and have stated that the maximum quantity of sorbite was obtained " by rapid cooling to below the critical point followed by tempering of the exterior by the internal heat of the partially chilled steel."*

These gentlemen, Messrs. Stead and Richards, have written a very interesting and instructive article upon this subject, but they have presented it as entirely new, while as a matter of fact in this country we have been making " sorbitic steel rails " for a good

*Iron and Steel Metallurgist*, Vol. VII ; J. E. Stead and A. W. Richards " Sorbitic Steel Rails," p. 36.

many years as the microscope will readily show; Messrs. Stead's and Richard's work has been then to make steel rails *more* sorbitic than has been done formerly, and with very good results as their figures will show.

Since the previously mentioned paper was published, the author has made other experiments along this line and finds that

(1)  the higher the temperature from which air cooling commences,

(2)  the smaller the sample,

(3)  the longer the specimen is kept at the high temperature,

(4)  the more rapid the air cooling,

the greater will be the amount of sorbite produced.

Treating these points separately, Fig. 3 shows a steel of 0.50
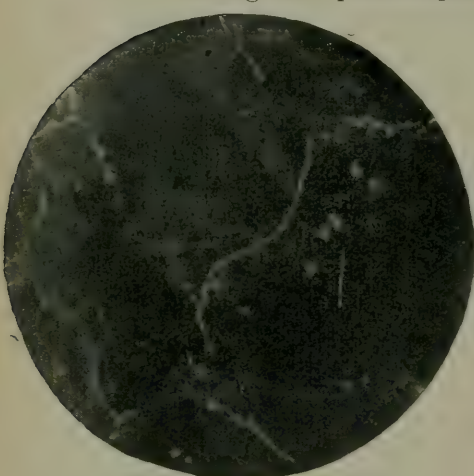


Fig. 3.   Air cooled from 1200° C.
          100 diameters.
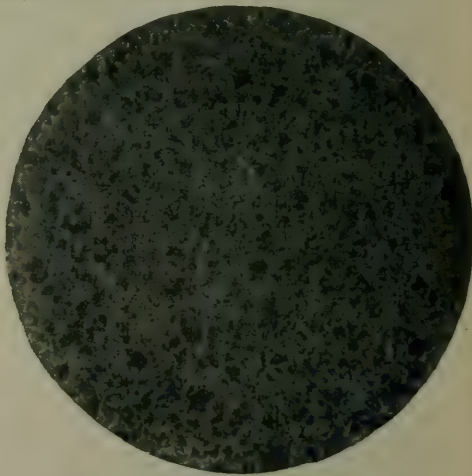
Fig. 4.   Air cooled from 900° C.
          100 diameters.

carbon cooled in the air from 1200° C., and Fig. 4 one cooled from 900° C.; it is evident that the dark constituent in Fig. 3 occupies much more of the total area than that in Fig 4; an examination with a high power microscope of this dark component shows that in Fig. 3 it is made up almost entirely of sorbite, while in Fig. 4 pearlite predominates. It follows from (1) that (2) must be true, as the smaller sample will cool much more rapidly than the large one; in fact, if it has a cross section of much more than one inch, a large part of the interior will be pearlite.

The reason for the fact that (3) the longer the specimen is kept at the high temperature the greater the amount of sorbite present is not quite clear; the fact remains, however, for Fig. 5 is an example of a piece of the same steel which was heated to 1150° C., kept there two hours, and then cooled in the air. The amount of sorbite present, as shown in Fig. 5, is very great, much exceeding that obtained in any other way. There is also
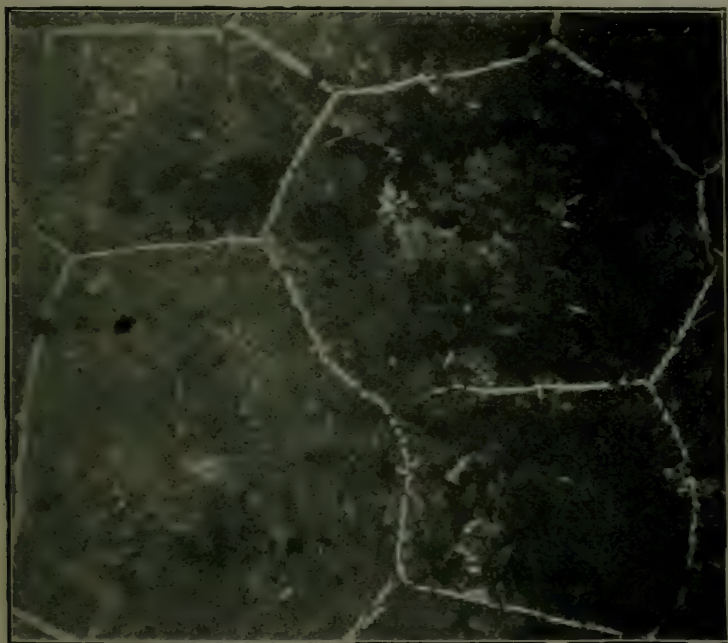


Fig. 5.   Heated 1150° C. for 2 hours.
100 diameters.

a tendency of the ferrite to form around the areas of sorbite a definite network made up of almost regular polygons, as the photograph shows.

(4)   That the more rapid the air cooling the greater the amount of sorbite present is easy to understand, for to the point where martensite would be formed, the more rapid this cooling through the critical point, the more ferrite would be retained in the solid solution which below the critical point forms sorbite.

Fig. 6 is a photomicrograph of such a steel heated to 1100° C. and cooled in an air blast. The amount of sorbite is large and the ferrite network is much broken up and is hardly ever continuous, there being many areas in the sample showing no free ferrite at all.

Another point which was brought forward in the previous paper,* was that as sorbite is an intermediate or transition form between martensite and pearlite, some of its carbon also must be in the hardening condition, or at least partially so. By the
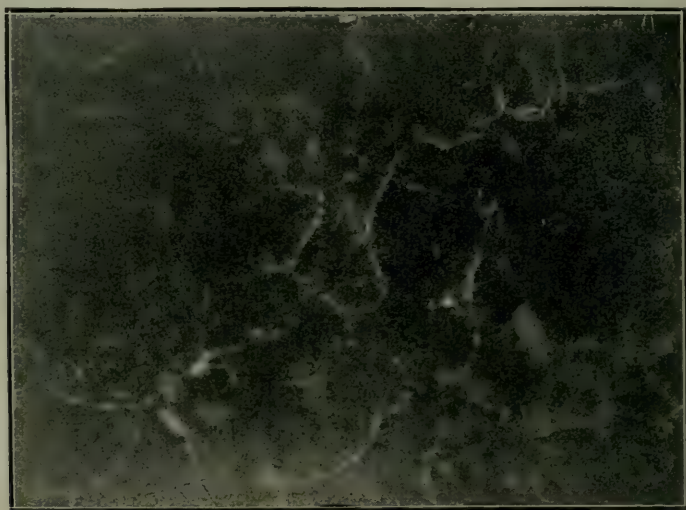


Fig. 6.    Heated 1150° C. cooled in air blast.
100 diameters.

color analysis, if this point be true, a steel made up principally of sorbite would give lower results than that made up wholly of pearlite, since some of the carbon in the former would pass away as volatile matter on dissolving the steel in nitric acid.

The author has tested this point very carefully and finds in the case of the air-cooled sample analyzed by the color method that decidedly lower results are obtained. Two pieces (two inches in length) off the same bar of a 0.48 per cent carbon forged steel were heated to 1200° C; in order that the amount of sorbite present might be large, one was cooled in the air

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*The Metallographist, Vol. VI, p. 155.

and the other in the furnace. Each of these pieces was cut in
two in the middle, and out of one-half, enough drillings were
taken for analysis; the other piece was prepared and polished
for microscopic examination.

The results have been tabulated below:

| Sample | Treatment | Dark Constituent | Color Anal. | Average |
|--------|-----------|------------------|-------------|---------|
| Steel 0.48% C. | Heated to 1200° C. furnace cooled | Pearlite | 0.48 | |
| " | Heated to 1200° C. air cooled | Sorbite | 0.36 | |
| " | Ibid. | " | 0.385 | 0.378 |
| " | Ibid. | " | 0.39 | |
| " | Heated to 1200° C. air blast cooled | " | 0.34 | |
| " | Ibid. | " | 0.35 | 0.345 |

The figures above were repeated times enough to confirm the
reasonable accuracy of the results. It can readily be seen by
taking the average of the different analyses that on analyzing
by the color method a sample cooled in air from a high tempera-
ture, the results obtained are just about 0.1 per cent too low; the
actual carbon content being found by combustion to be 0.48 per
cent, while the air cooled sample showed only 0.38 per cent. By
increasing the rapidity of the cooling by using a cold air blast,
the results are still further lowered by 0.13 to 0.14 per cent, and
there is probably no doubt but that this loss would be still further
increased if the cooling be hastened still more. It is interesting
to note that this apparent loss of carbon is not due to decarburiza-
tion as a result of the heat treatment, for the author has analyzed
by combustion a steel bar before treatment, then by air cooling and
furnace cooling respectively produced sorbite and pearlite in the
two specimens off this same bar; on taking drillings from these
two differently treated samples, no practical change whatever
was found in the second combustion analyses of the specimens
containing respectively sorbite and pearlite.

These results forcibly illustrate the important fact that in

order to obtain accurate results by the color method, the steel sample should be properly annealed before drillings are taken for analysis. Failure to do so will lead to low results. The author hopes that this record of his experiments will receive from steel chemists the attention which it seems to deserve.

In view of the fact that air cooling so greatly increases the tenacity and elastic limit of an undersaturated steel, it seemed natural to try the same treatment on a hypereutectic sample.

Therefore two pieces 14 inches long of ½-inch, round, 1.11 per cent carbon steel were taken and heated to 1150° C.; on reaching this temperature one bar was taken out and allowed to cool undisturbedly in the surrounding air, which was about 65° F.; the other piece was left in the furnace and cooled very slowly with it over night, the furnace still being about 100° C. when the steel was removed the next morning.

On testing with the Riehlé machine, the results obtained were somewhat surprising, as it had seemed to the author that the excess of cementite being so small in the steel would very rapidly separate out from the martensite when cooled through the critical point, and no material difference in structure would result. The figures are given below:

| Treatment of Sample | Character of Dark Constituent | Elastic Limit Lbs. per Sq. In. | Tensile Strength Lbs. per Sq. In. | Elongation Per Cent in 4 in. | Reduction of Area Per Cent |
|---|---|---|---|---|---|
| Heated to 1150° C. and cooled in furnace . . | Pearlite | 48,894 | 100,663 | 4.5 | 0.054 |
| Heated to 1150° C. and cooled in air . . . . | Sorbite | 100,148 | 140,148 | 4.4 | 0.039 |

As can be seen at a glance, the air cooling did not deprive this steel of any ductility (although of course the ductility is small in any case), but it doubled the elastic limit and increased the tensile strength by about 40 per cent. This experiment was repeated to see if by a possibility a mistake had been made, but practically the same figures were obtained.

An explanation of this great increase of elastic limit and tenacity by simple air cooling is given by the microstructure.

Fig. 7 is a low power photograph of the furnace-cooled steel mentioned above, and Fig. 8 the air-cooled sample. At this magnification practically no free cementite is visible in Fig. 8, but in Fig. 7 a good quantity is present, surrounding the grains of pearlite. Figs. 9 and 10 are higher powers of these two specimens and show the points more clearly; there is in Fig. 10 a very thin network of free cementite surrounding the dark constituent, which in this case also cannot be true pearlite, since it contains too much cementite, as the photograph readily shows. It is, then, this relatively greater diffusion of the hard, strong
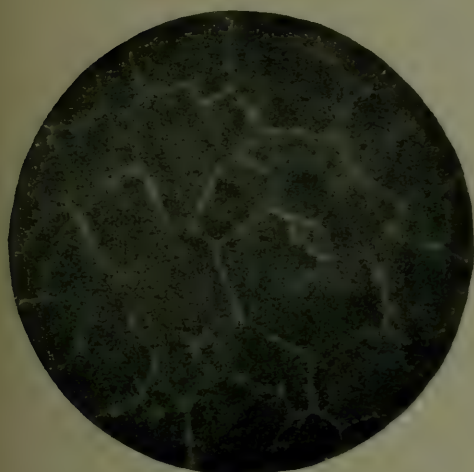


Fig. 7. (1.11% C.)
Heated 1100° C., furnace cooled.
100 diameters.
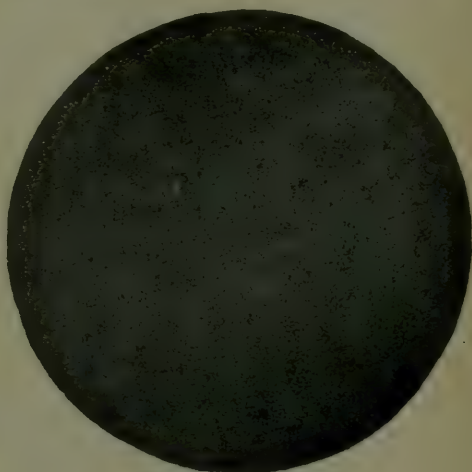
Fig. 8. (1.11% C.)
Heated 1100° C., air cooled.
100 diameters.

carbide of iron through the mass of iron that makes the metal possess a much higher tenacity than the furnace-cooled sample, where all the free cementite had time to segregate out, forming a good network about the grains of pearlite. This network of cementite in the furnace-cooled sample (see Fig. 9) is evidently a source of weakness, for although very hard, cementite possesses brittleness to a marked degree, as is evident in white cast iron, where it is present in large quantities.

To explain the phenomenon of cooling a little more in detail, the steel used contained 1.11 per cent. carbon; this steel is evidently supersaturated, that is above the eutectic ratio, 0.80

per cent for commercial steel.  On heating to 1100° C., all of the carbon present is contained in the solid solution, martensite; on cooling slowly through the critical point some of this carbon must be thrown off in the form of cementite, so that the remaining mass (hardenite) must contain 0.80 per cent carbon.  Below the critical point the rejected cementite remains unchanged, but the hardenite (containing 0.80 per cent carbon) passes into the form which is in equilibrium at the ordinary temperature, namely, the eutectic alloy, pearlite.

By hastening the cooling, a very natural consequence ensues. Just above the critical point, since the cooling is too rapid for the complete removal of the excess of cementite (that above 0.80 per cent carbon), some of it is retained in the solid solution, which now cannot be called hardenite, and which below the critical point shows a very much larger amount of $Fe_3C$ than the eutectic alloy.

The two diagrams shown below may illustrate a little more clearly the points brought out.

*Changes in Structure of a Slowly-Cooled 1.11 Per Cent Carbon Steel*

| Above recalescence | Martensite (100%) | |
|---|---|---|
| During critical range | Hardenite (95%) | Cementite (5%) |
| Below critical point | Pearlite (95%) | Cementite (5%) |

*Changes in Structure in an Air Cooled 1.11 Per Cent Carbon Steel*

| Above recalescence | Martensite (100%) | |
|---|---|---|
| During critical range | Hardenite? (97—99%) | Cementite (1—3%) |
| Below critical point | Sorbite? (97—99%) Cementitic pearlite? | Cementite (1—3%) |

This alloy with the excess of cementite, can it be called pearlite?  Can it be called sorbite?  If we call it sorbite, which
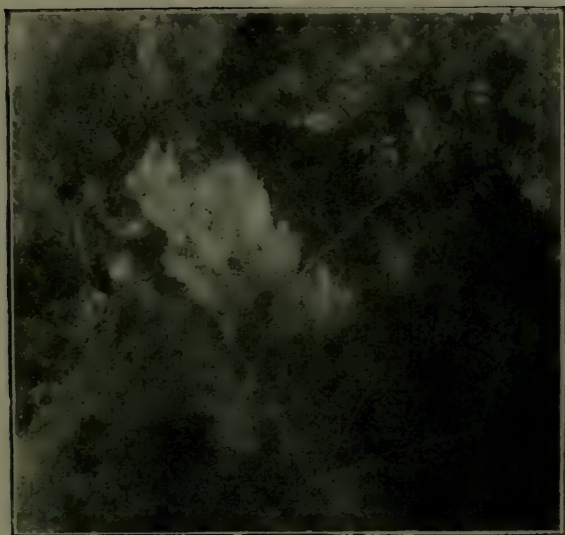
Fig. 9.   (1.11% C.)
Heated to 1100° C. and furnace cooled.
500 diameters.
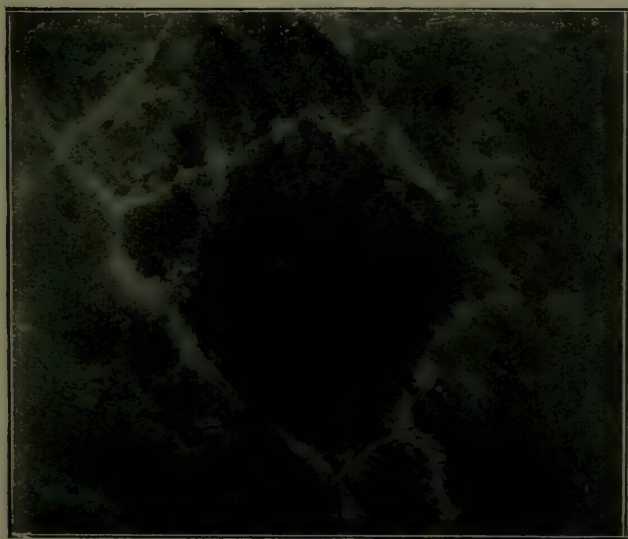


Fig. 10.   (1.11% C.)
Heated to 1100° C. and air cooled.
500 diameters.

has always been considered as a " ferrous or dilute pearlite," since this alloy contains an excess of cementite, we must extend to sorbite a variable carbon content, as in martensite and austenite.

To sum up briefly, the principal points which have been brought forward in this paper are as follows:

(1) furnace cooling of an under saturated steel produces ferrite and *pearlite;*

(2) air cooling of the same steel produces in samples of relatively small section, ferrite and *sorbite;*

(3) the composition of sorbite depends upon the rate of cooling;

(4) the carbon in sorbite is partially in the hardening condition, therefore all specimens subjected to " color analysis " should be previously annealed;

(5) air cooling of a supersaturated steel greatly increases the tensile strength and elastic limit, producing a structure made up of pearlite containing an excess of cementite, and less free cementite than under furnace cooling.

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## IMPERFECT EQUILIBRIUM IN ALLOYS[*]

By F. OSMOND
Paris, France



LET us imagine two metals $M$ and $N$ which do not form any definite compound nor undergo any allotropic transformation, which are mutually soluble in each other when liquid, but only in a constant and limited degree when solid. The curves representing the equilibrium of the various phases which can exist at all possible temperatures below that of volatilization will be, as is well known, represented by the type of Fig. 1. $A$ is the point of

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[*] Received October 22, 1903.

solidification of $M$, and $C$ that of $N$. The curves $AB$ and $CB$ represent respectively the temperatures at which for each alloy of the series the solution of $N$ or that of $M$ begins. $B$ is the eutectic point and $DE$ is the eutectic branch, which indicates the simultaneous solidification of both metals. In cases of alloys differing from the eutectic, the solidification is progressive and finishes as shown by the curves $AD$ or $CE$ in the case of alloys whose content is inferior to that of saturated solid solutions, and as indicated by $DE$ in the case of others. After cooling $M$ contains $OF$ per cent of $N$, and $N$ contains $GX$ per cent of $M$ in solid solution.
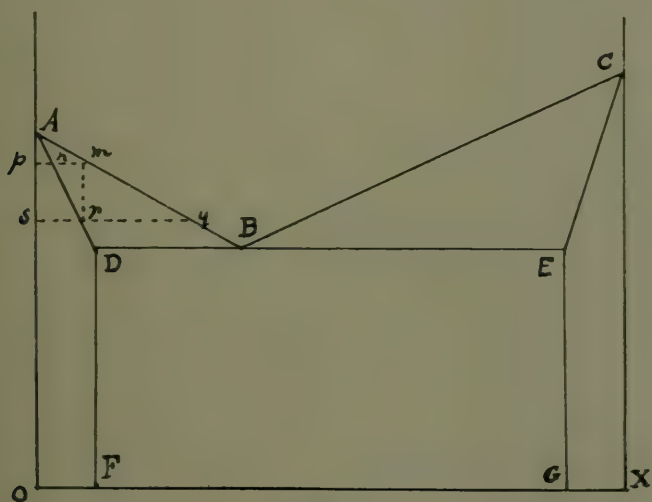


Fig. 1.

In the case of an alloy of given composition containing for instance $mp$ per cent of $M$ and 100—$mp$ of $N$, it is known, as shown by Roozeboom and confirmed by others, that the first portion of $M$ which solidifies at the point $m$ is less rich in $N$ than the liquid from which they solidify. The remaining solution therefore becomes richer in $N$ and its solidification point is lowered: the new crystals formed are therefore also richer in $N$ than the first ones, and solidification proceeds in this way until the last mother liquor solidifying at $O$ gives up crystals whose content in $N$ is equal to that of the original alloy. This, however, supposes that $N$ diffuses uniformly in the solid solution as solidification proceeds. Such

is not necessarily the case.  Molecular motions are generally slow in solids, the more so as the temperature is lowered below the solidification point and they frequently cease at ordinary temperature.  If the cooling is not slow, therefore, the equilibrium will not be obtained immediately and will possibly never be reached.

Let us suppose for the sake of simplicity that the two substances $M$ and $N$ when solid are not soluble in each other whatever the temperature.  Instead of forming finally two solid solutions respectively homogeneous, the alloy, for instance the one which contains $mp$ per cent of $N$, will solidify in layers; each layer containing an increasing proportion of $N$.  Starting from the axis $ab$ and $cd$ of the crystallites, and finally, even in the case of very small proportions of $N$, nucleus, $e$, $e$, $e$, of eutectic will be
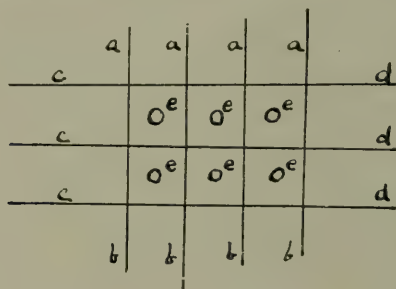


Fig. 2.

obtained in the center of the islets formed by the crossing of the crystalline axis.

In practise the diffusion will not generally be either nil or complete and homogeneous.  The presence of the eutectic will be found therefore in alloys containing less of the metal $N$ than should be expected according to the theory, but not in all alloys, and the proportion in $N$ of the crystallites will increase from the axis.

In what precedes, we have supposed that the solid solubilities were constant below the temperature of the solidification of the eutectic.  In fact the solubilities generally diminish with the temperature and the resulting diagram belongs to the type shown in Fig. 3, in which the curves $DF$ and $EG$ approach the axis instead of being vertical as in Fig. 1.

A solid solution containing $Ou$ per cent of $N$ whose solidi-

fication was complete in *r* and which we shall suppose this time
to be homogeneous will allow the metal *N* to be deposited
between temperatures *t* and *u*. A solution which is saturated at
the temperature of solidification of the eutectic will deposit the
alloy all along the line *DF*, that is to say, from the point of solidi-
fication to the ordinary temperature.

This metal *N* deposited in this manner by the cooling solid
solution, however, will have a tendency to unite with the same
metal forming part of the eutectic, or if no eutective be present,
it will have a tendency to collect at the places which the eutectic
would have occupied, that is to say, at points the farthest away
from the axis of the crystallites.
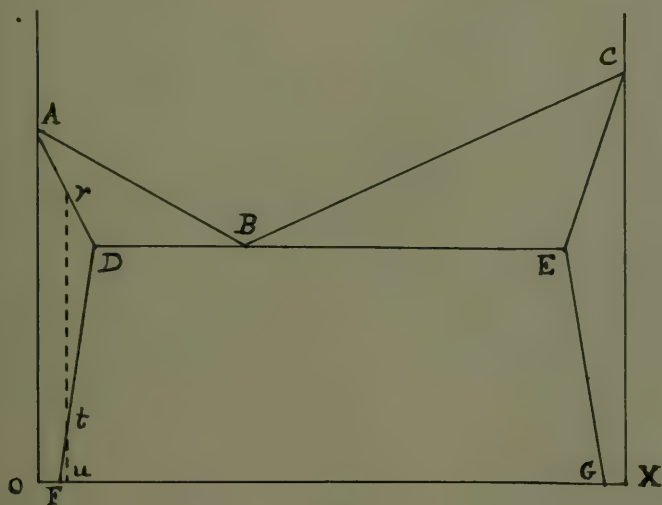


Fig. 3.

If the cooling be rapid, however, if the speed of diffusion
of *N* in *M* be weak and becomes nil above the ordinary tempera-
ture, this concentration of the portion of the metal *N* separated
from the solid solution will take place only incompletely, and this
condition will be maintained indefinitely. This results in a
second cause of heterogeneousness which must be added to the
first one already referred to, that is to say, to the method of
solidification by layers of varying composition without simul-
taneous, homogeneous distribution.

These facts have little bearing upon the phase rule whose purpose is to establish permanent equilibriums. They are, however, of much interest to those engaged in the working of alloys, and who study them from the point of view of their applications. If an alloy instead of being made up of homogeneous phases, as called for by the theory, is composed of layers of varying composition, its mechanical properties will be either better or worse; they will surely be different. As it is impossible to infer these properties, each case must be studied carefully for the conduct of the manufacture and in order to obtain certain desired results. Such instances are frequent. Witness the bronzes containing less than 9 per cent of tin (Charpy), and certain alloys of copper and antimony. (Stead, *The Metallographist*, 11,325.)

I have had the opportunity to study one of these cases several years ago when engaged in investigating alloys of copper and silver at a time when we were not guided by Roozeboom's theory. I was not then able to understand results which to-day are very clear and which should now be published.

In order to ascertain the solubility of solid copper in solid silver I was trying to find at what percentage the copper which can readily be distinguished by its color, began to appear as small isolated grains on the surface of a polished sample, when examined under the microscope. To that effect I had cast, alloys containing respectively 0.25, 0.50, 1, 2, 4, per cent of copper. The melting was effected in small crucibles under a layer of borax and of charcoal in a Leclercq and Forquignon furnace. The alloy was allowed to solidify and to cool in the furnace and as the latter was very small the cooling was relatively rapid. The silver used was obtained from the reduction of pure chloride. A few peculiarities were observed when one of these polished sections was gradually heated in the air to about 500 degrees while observing the section under the microscope by oblique light which is possible with low powers. At a certain time crystallites were seen suddenly to form appearing light on a dark background (Fig. 4), which means that the surface of the crystallites was the first to lose its color and to reflect into the objective some diffuse light, while the black areas remained polished and continued to reflect the light outside the objective.

At a higher temperature these appearances are reversed; the crystallites become dark on a light background. At a still

higher temperature the appearance of the section became uniform. These phenomena are very peculiar and not to be expected in a pure metal. It is possible that the silver used had dissolved a little carbon during melting; for it is hardly possible to conceive a difference of crystalline orientation independent of any division into grains.

A higher magnification did not reveal any new feature. After etching several minutes in nitric acid a palm-leaved appearance was obtained having no relation to the crystallitic structure, which I never noticed in any other preparation. I cannot offer
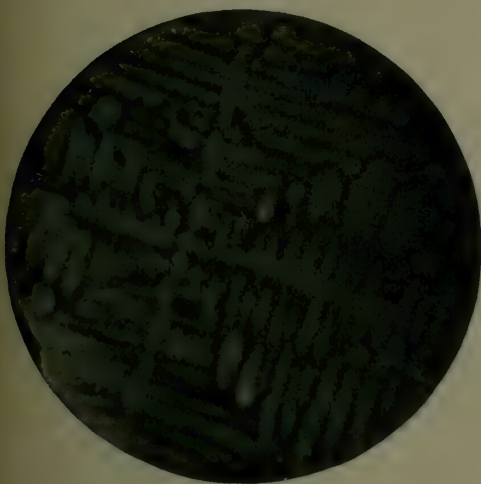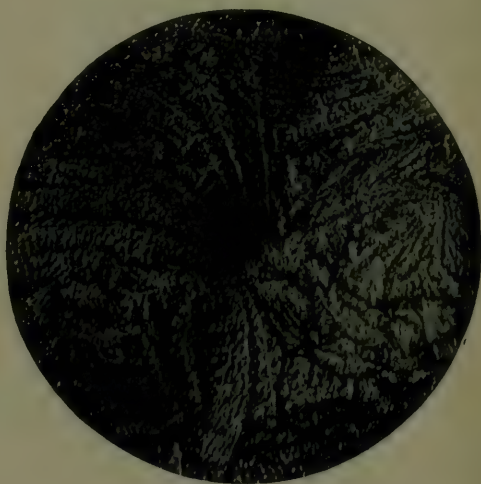


Fig. 4.                                    Fig. 5.

any explanation for this structure and I mention it here because of its peculiarity (Fig. 5).

Alloys containing 0.25 and 0.50 per cent of copper do not differ from pure silver; the copper therefore must be diffused in them in the shape of a solid solution.

With one per cent of copper some small particles of copper can be detected between the crystallites. The saturation point of the solid solution is now passed. If the sample be heated in the air the metal around these small particles of copper and elsewhere is colored yellowish brown while the copper itself assumes a blue color. As silver is not oxidized under these conditions this color-

ation must indicate a progressive concentration of the copper in the regions of last consolidation. We find in this a confirmation of the general considerations presented at the beginning of this note. Homogeneous distribution was not complete and we have here an imperfect equilibrium (Fig. 6). With two per cent of copper many small copper grains are found occupying 0.88 per cent of the total area as ascertained by the planimeter. The balance is in part in solid solution, and, in part, concentrated around the free copper. The portions thus colored are here larger than in the case of the alloy containing one per cent of copper. The crystallites are also smaller.
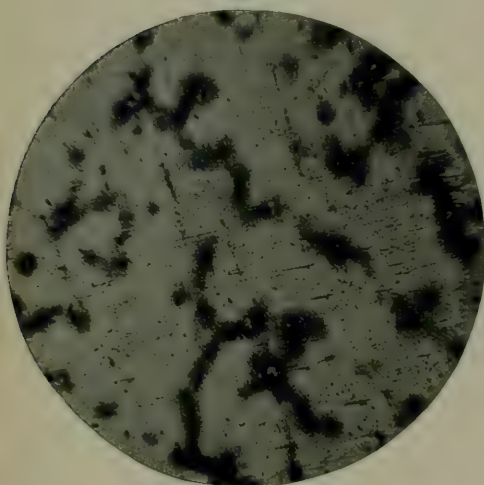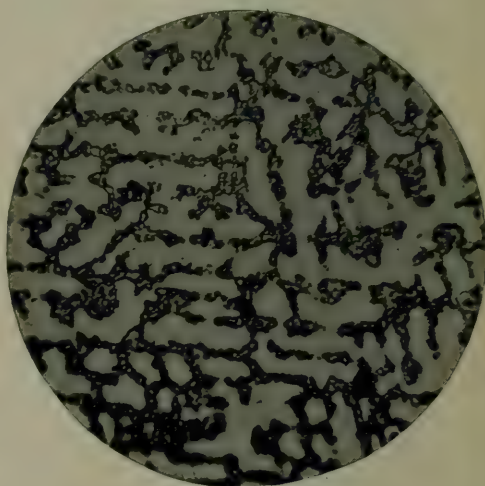


Fig. 6.　　　　　　　　　　　　　　　　Fig. 7.

With four per cent of copper the spaces between the crystallites, which are now still smaller, are filled with eutectic. Upon heating, however, the silver contained in the eutectic becomes brown while the silver in the crystallites is not colored (Fig. 7). The silver of the eutectic, therefore, contains beside dissolved copper an excess of copper diffused, but not dissolved for reasons already given. The isolated copper amounts to 3.08 per cent.

Besides the information which these experiments give with regard to the causes of lack of uniformity of solid solutions, they raise a question of very great importance to the philosophy of chemical sciences.

We have no precise knowledge of the state of substances in solid solution, but it is probable that molecular condensation is seldom the same in the case of a body in solution and of an isolated body. On the other hand, it may be conceived that the substance previously dissolved, when it comes to be precipitated at a temperature so low that diffusion is impossible, retains the molecular condition which it had when in solution, the isolated molecules lacking the power to unite. The possibility of the existence of molecules of the liquid or gaseous type even of independent atoms in solid substances follows from these considerations. This conception which originated with Graham appears again here under a more probable form, and it will possibly suggest research, the nature of which cannot now be foretold.

## A RAPID METHOD FOR THE DETERMINATION OF TOTAL SULPHUR IN IRON BY EVOLUTION *

### By S. S. KNIGHT

THE recent modification of the method for determining sulphur in iron presented by Walters & Miller of Pittsburgh, Pa., had as its principal disadvantages the extraordinarily long time, which they claim would be at least an hour, under the most favorable circumstances to complete a sulphur determination and also the expensive and unusual apparatus for roasting samples in a current of reducing gases.

In commercial laboratories which are not equipped with this apparatus the recent modification of this roasting process has consisted in roasting the weighed sample for a period of one hour at a slowly increasing temperature. The culmination of this annealing process was the highest heat obtainable before a blast lamp which was continued for at least fifteen minutes. The sample thus roasted was treated as heretofore by the Evolution process.

In the laboratory of the Birmingham Pipe and Casting Company the writer has been able to get results which check very closely with those obtained by the above described method, and also with those obtained by the barium chloride gravimetric method by the following process : — The weighed sample, which in our case consisted of two grammes, was mixed with one gramme of

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the purest iron dust by hydrogen obtainable and in which the sulphur content had been previously determined. This mixed sample is then placed in a small porcelain crucible and one gramme more of the iron by hydrogen is sprinkled over the top so as to form a continuous covering. On top of this is placed a small disc of quantitative filter paper, the lid is then placed on the crucible and this is placed on the triangle over the blast lamp. For ten minutes the highest heat obtainable with the blast lamp is used in roasting this mixture, at the expiration of which time it is allowed to partially cool, and the contents of the crucible are then placed in the ordinary evolution flask and treated with hydrochloric acid, while the evolved gases are washed in any of the common forms of absorption bulbs. The absorbent liquid in our case has been an ammoniacal solution of cadmium chloride which was afterwards titrated with the iodine solution of known strength. The results obtained by this method are exactly those given by standard gravimetric methods, and also the same as those obtained by Walters & Miller's method, while the time consumed is something less than one-half hour from the time the sample arrives in the laboratory. It is believed by the writer that the advantage of this modification will be readily appreciated by chemists in charge of commercial laboratories.

## THE ALLOYS RESEARCH COMMITTEE *

WHATEVER revelations and surprises the future may have in store for engineers, we cannot help thinking that some of the most useful, if not the most startling, will be due to the untiring labors of the Alloys Research Committee of the Institution of Mechanical Engineers, whose guiding spirit was the late Sir William Roberts-Austen. Who would have thought only a few years ago that the microscopical researches of various earnest men would have revealed all that they have done of the internal constitution of iron and steel; or who would have ventured to predict that the discovery of the thermo-couple pyrometer, whereby high temperature can be read with exactitude, would be the prelude to discoveries the importance of which can be as yet only dimly seen? To the engineer of ten years ago, even though he

* "Engineering," London, February 12, 1904.

were a man conversant with all known processes of iron and steel manufacture, the words " ferrite," " cementite," " pearlite," " austenite " and " martensite " would not have conveyed any intelligible meaning. Yet to-day in the lecture halls of our engineering societies these are becoming household words. True, there are those to whom they convey but little meaning even now, but time will rapidly change this, and our engineers, through the researches of such men as Stead, Arnold, Hadfield, and others, will become familiar with the lessons taught by the investigations now going on, more particularly, perhaps, with regard to iron and steel, until they are able to produce material having given properties for certain purposes, with an exactitude which a few years ago would have been deemed little short of impossible. All this is well, for the more earnestly we strive after knowledge of this kind, the better able shall we be to hold our own in the struggle of the nations. In view of this fact, it is highly satisfactory that in this particular branch of knowledge the younger members of the profession have not been forgotten. We refer to the lecture delivered by Mr. W. H. Merrett, A.R.S.M., to the graduates of the Institution of Mechanical Engineers on the evening of the 8th inst., on the " Alloys Research Committee." In this lecture, the salient points of the work of the Alloys Research Committee during the last few years were dealt with, as well as matter not referred to in the Proceedings. The early portion of the lecture was more or less historical, bearing on the work done by the late Sir William Roberts-Austen and Sir William Anderson; and it showed clearly how impossible the work would have been but for the discovery of the thermo-couple recording pyrometer, by means of which an exact register of high temperatures can be taken. As is now well known, the action of these pyrometers depends on the electric current which is produced when a thermo-couple, formed of platinum on the one side and platinum iridium on the other, is raised in temperature, the current produced deflecting a galvanometer which carries a mirror. The galvanometer and mirror are placed in a dark box, through a hole in which a ray of light falls on the mirror from a lamp outside the box. This ray of light, when it is reflected from the mirror falls on a photographic plate, which, as the ray of light moves along it, owing to the mirror being deflected by the electric current, records automatically any temperature that may be obtained.

By means of diagrams the typical freezing-points of pure metals and of a metal containing eutectic were shown; also the best form of crucible to be used when carrying out experiments on molten metals was described, as well as the best way of inserting the thermo-couple in the metal.

Among other things, the lecturer describes how sodium will pass through plain glass from sodium amalgam to pure mercury, and the glass will remain quite clear; while with lithium amalgam, although the lithium would pass through the glass, the latter becomes brittle. Some very interesting curves of copper-tin alloys were exhibited for the first time, and these showed that in some cases the alloy has three freezing-points.

When touching on the fourth report of the Alloys Research Committee, the lecturer explained how it has been discovered that the strength of alloys of metals of different atomic volumes was much higher than that of alloys in which the atomic volumes of the metals forming it were the same.

Interesting as the whole of the researches of the Committee are, we cannot help thinking that — to engineers, at any rate — the equilibrium curves of the carbon-iron series are particularly so; and it is little short of marvellous what an intimate knowledge has been gained of the behavior of different alloys of iron and carbon, while passing from the molten state to the solid, and it is not always easy to grasp the idea that steel obeys the ordinary laws of solution.

Mr. Merrett showed by means of numerous lantern slides the wonderful effect produced on steel by different methods of heat treatment, and explained how it was that a certain steel, if treated in one way, might appear quite worthless for the purpose for which it was intended; while, if treated in another way, it would prove to be all that could be desired. And this is what the Research Committee are doing for engineers, to tell them exactly how to treat different steels for different purposes, and in so exact a manner that certain results can be relied upon to follow certain treatment. We are not at all sure that engineers yet quite appreciate the full benefit that is likely to accrue from this. It appears to us vast in its far-reaching results, and we look forward with keen anticipation to what the next few years may bring forth. The whole outlook is one of much promise, and is surrounded by so many issues that it is quite impossible to foresee whither the present course of investigation may tend.

# WROUGHT IRON BY THE REYNOLDS PROCESS *

### By JAMES N. WHITMAN

THE Reynolds process for making wrought iron resembles in practice and product that of the old " Catalan Forge." Improvements made by the substitution of pulverized bituminous coal for fuel in place of charcoal, mechanical action of the rotary furnace in place of skilled labor, and adaptability to chemical handling of all material have resulted in cheapening the cost of a very desirable product, and have brought forged blooms and bars within reach of the makers of crucible and open-hearth steel and of manufacturers of iron bars of a superior quality.

In practice the finely pulverized ore is intimately mixed with finely pulverized carbonaceous material, then charged into the body of a rotating furnace, where the ore and carbon are most thoroughly exposed to the heat necessary to deoxidize and carburize the ore. After the ore has been reduced in a CO atmosphere the flame is changed to $CO_2$ and the reduced ore is decarburized and brought up to a heat sufficient to weld the material into one solid ball ready for the hammer and squeezer.

Practice has shown this to be an exceedingly simple, short, and perfect operation. The use of pulverized coal makes it possible to obtain a flame neutral at all times to the operation being carried on in the furnace, it being practical to secure and maintain for as long a period as required either CO or $CO_2$ flame.

As there are no additions to introduce impurities in the finished product there is no reason why wrought iron produced by this process should not be as good chemically as the ore from which it is made.

Experiments made with a furnace of full capacity using " Chateaugay concentrates " produced a bar which forged and welded well both at a very low and a very high temperature. The bars proved to very strong cold, and resemble in appearance and manner of working Swedish iron bars.

There were no facilities at hand for squeezing or rolling the balls produced in the furnace. These had to be reheated and worked under the hammer, so that in the material actually made but little of the scoria has been removed. In practice the slag

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and scoria would of course be expelled in the squeezing and rolling operations in the customary manner.

There are many iron ores in which impurities are not chemically combined, and to remove which it is necessary to crush the ore to a fineness which makes it impractical for use in the blast-furnace without briquetting. By the Reynolds process the more finely divided the ore particles are the more economical is their treatment in the furnace, so that many large deposits of ore which are now of little or no value would be those which are more adaptable for treatment by this process.

There is no doubt whatever as to the great advantage of the intimate mixing of the fine particles of ore and carbon. Since deoxidation and carburization take place only at the point of contact, indefinitely multiplying these points wonderfully increases the speed of the operation. Actual practice has proved that the ore can be converted into wrought iron of a superior quality in a remarkably short time and at a great saving, both in labor and material, over any other process.

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## THE CONTINUOUS STEEL PROCESS IN THE OPEN-HEARTH FURNACE*

IN a recent issue of " Stahl und Eisen," Herr S. Surzycki advances the claim that, putting on one side the earlier attempts of Mr. F. Siemens and others which have found no practical application, the employment of a fixed open-hearth furnace with more tap holes on the tapping side is not new. On the contrary, since September, 1902, the continuous working of an open-hearth furnace has been carried out by Herr Surzycki at the works of the B. Hantke, at Czenstocha, with satisfactory results.

This practice consists essentially in the arrangement of two or more tap holes situated one over the other, but not in one line, which lead into a double spout, by which the whole or only a part of the contents of the furnace are easily tapped, at any time. The accompanying cut explains this. These openings are arranged in a cast-iron plate which is bricked with magnesite bricks and stamped with dolomite. They answer admirably, and during a continuous campaign of several weeks they neither shift nor

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* " Iron and Coal Trades Review," March 11, 1904.

sink, nor even corrode; the same may be said of the hearth, which, without any repair, remains sound for months. At first, at Czenstocha a 20-ton furnace was employed experimentally on this process. The results obtained were very favorable, and a 30-ton furnace was then built in the same way. A larger and deeper and wider furnace is now being built.

The process is carried out in the following manner: — The furnace is first charged with cold, clean scrap. As soon as this has reached the melting point, molten pig iron direct from a blast furnace or from a mixer is poured in; when the bath is quite
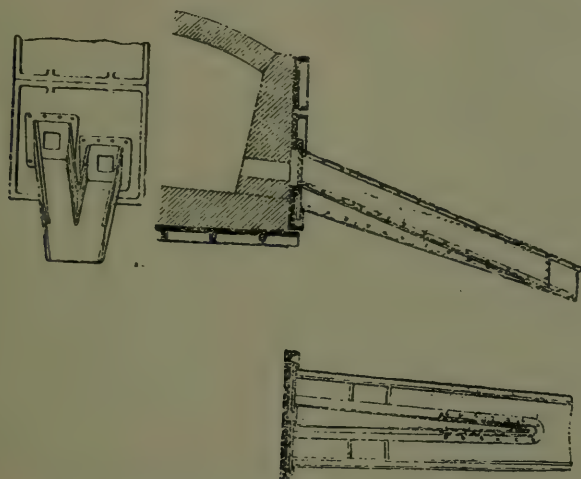


Tapping Holes and Spout of Open-Hearth Furnace.

quiet and perfectly melted, a considerable amount of iron ore and mill scale is added, and after that a further amount of pig iron is poured in. The charging lasts until the furnace is quite filled up; the charge is dephosphorized in the ordinary way by additions of lime, and when decarbonization has reached the required point the furnace is tapped. With a 20 to 25-ton furnace, which, by making the hearth deep enough, can hold from 45 to 50 tons of molten metal, the tapping holes are so arranged that charges of 25 to 30 tons of metal are tapped, leaving from 25 to 30 tons behind in the furnace. The deoxidation, that is the making ready of the steel, is carried out by means of wood carbon and ferro-manganese additions made in a ladle by throwing carbon in small

pieces and ferro-manganese into the ladle during the tapping of the charge, whereby there is produced a lively reaction which is characterized by a high flame; but the contents of the ladle soon become perfectly quiet, and one can then proceed to cast the ingots. Large ingots of about one ton weight down to small ones of about 300 pounds, for beams, angles, merchant iron, wire, etc., are cast. The steel remains quite quiet in the ingot moulds, and can be rolled perfectly, and shows in every respect a perfectly satisfactory homogeneous quality. After tapping, the upper tap-hole is easily and quickly closed in the ordinary manner with dry burnt dolomite, and the furnace repaired. As a rule only the slag line, and, to a less extent, the blocks require repair. There is then added a calculated amount of ore and roll scale, and an amount of pig iron corresponding to the amount tapped is run in. By this last operation a very lively reaction is brought about, with a considerable development of heat, so that the interior of the furnace becomes strongly heated, although the gas and air remain shut off. Through this reaction a considerable purification of pig iron takes place, which is an advantage, and is, indeed, necessary in reference to the duration of the process. In this way the practice is carried on uninterruptedly usually from one to two weeks. When from any cause the remainder of the furnace contents must be cast this is easily done by opening the lower tap-hole.

This practice has been carried out at the Czenstocha Works for a year, and the results obtained have been eminently satisfactory. A furnace which, with cold additions only, holds from 25 to 27 tons, and when working 80 per cent pig iron and 20 per cent scrap makes some 65 to 70 tons of ingot in 24 hours, reaches by the above continuous process from 75 to 90 tons of ingot iron in the double shift by the employment of some 20 to 25 per cent of iron ore and roll scale, and a yield of 101 to 102 per cent (calculated on the metallic additions). It must be remarked that the pig iron used contains 0.6 to 0.8 per cent of phosphorus, and that the furnace is very shallow and narrow (8 feet 8 inches and 20 inches deep in the hearth).

With the continuous smelting process the proportions of the tapped and the remaining metal are of the highest importance for the output of the furnace, a fact which has been repeatedly emphasized by Mr. Benjamin Talbot, and which has been fully confirmed by practical experience with large furnaces both in

America and England. The greater the capacity of the furnace and the larger the mass of the metal remaining in the furnace, compared to the mass of the tapped metal, the less time is wanted for each heat, and the larger is the output.

The above-described continuous steel melting process, which is based on the Talbot process, has this essential advantage — that it may be worked in an ordinary fixed furnace, if not too small, and that the necessary apparatus may be supplied in a very short time and at a very low cost, whereas the erecting of a tilting Talbot furnace involves a considerable capital, but for the rest it offers the same advantages as the continuous steel smelting process.

## THE UNITED STATES STEEL CORPORATION *

THE second annual report of the United States Steel Corporation, for the year ended December 31, 1903, has been issued. Some of its statements, covering the operations during the year of the Corporation and its subsidiary companies, are of great interest and are given below.

The production of the several properties for the year, in comparison with the results for the fiscal year 1902, in tons, is shown in the table on page 496.

The total net earnings of all properties after deducting expenditures for ordinary repairs and maintenance (approximately $22,000,000), also interest on bonds and fixed charges of the subsidiary companies, amounted to $109,171,152.35. Appropriations for sinking funds on bonds of subsidiary companies, depreciation and extinguishment funds, extraordinary replacement funds, and special fund for depreciation, improvements, and construction amounted to $25,495,365.84; leaving a balance of net earnings in the year 1903 of $83,675,786.51. From which there has been deducted interest on U. S. Steel Corporation 50 year 5 per cent gold bonds, $15,195,850; interest on U. S. Steel Corporation 10-60 year 5 per cent gold bonds, $3,886,946.38; sinking fund on U. S. Steel Corporation 50 year 5 per cent gold bonds, $3,040,-000; and sinking fund on U. S. Steel Corporation 10-60 year 5

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per cent gold bonds, $757,500; total, $22,880,296.38. The balance amounts to $60,795,490.13. Less, $5,378,837.63 charged off for depreciation in inventory valuations and for the adjustment of sundry accounts. Balance, $55,416,652.50. Dividends for the

*Table showing the production of the several properties, in tons:*

| Products — Tons | 1903 | 1902 |
|---|---|---|
| Iron ore mined: | | |
| From Marquette Range | 1,412,402 | 1,487,370 |
| From Menominee Range | 2,106,443 | 2,675,754 |
| From Gogebic Range | 1,867,856 | 2,064,492 |
| From Vermilion Range | 1,918,584 | 2,057,537 |
| From Mesabi Range | 8,058,070 | 7,778,026 |
| Total | 15,363,355 | 16,063,179 |
| | | |
| Coke manufactured | 8,658,391 | 9,521,567 |
| Coal mined, not including that used in making coke | 1,120,733 | 709,367 |
| Limestone quarried | 1,268,930 | 1,313,120 |
| Blast furnace products: | | |
| Pig iron | 7,123,053 | 7,802,812 |
| Spiegel | 121,779 | 128,265 |
| Ferro-manganese and ferro-silicon | 34,409 | 44,453 |
| Total | 7,279,241 | 7,975,530 |
| | | |
| Steel ingot production: | | |
| Bessemer ingots | 6,191,660 | 6,759,210 |
| Open-hearth ingots | 2,976,300 | 2,984,708 |
| Total | 9,167,960 | 9,743,918 |
| | | |
| Rolled and other finished products for sale: | | |
| Steel rails | 1,934,315 | 1,920,786 |
| Blooms, billets, slabs, and sheet and tin-plate bars | 493,292 | 782,637 |
| Plates | 519,713 | 649,541 |
| Merchant steel, skelp, shapes, hoops, bands and cotton ties | 997,595 | 1,254,560 |
| Tubing and pipe | 795,821 | 744,062 |
| Rods | 101,699 | 109,330 |
| Wire and products of wire | 1,126,605 | 1,122,809 |
| Sheets — black, galvanized, and tin-plate | 855,215 | 783,576 |
| Finished structural work | 469,692 | 481,029 |
| Angle and splice bars and joints | 138,709 | 139,954 |
| Spikes, bolts, nuts, and rivets | 53,259 | 42,984 |
| Axles | 119,716 | 136,787 |
| Sundry iron and steel products | 30,059 | 29,177 |
| Total | 7,635,690 | 8,197,232 |

year 1903 on U. S. Steel Corporation stocks, viz.: preferred, 7 per cent, $30,404,173.41; common, 2½ per cent, $12,707,562.50; total, $43,111,735.91. Leaving undivided profits or surplus for the year, $12,304,916.59, against $34,253,656.75 for the preceding year, a decrease of $21,948,740.16.

The outstanding capital stock of the United States Steel Corporation was reduced during the year by the retirement of $150,-000,000, par value, of preferred stock, in lieu of which an equal amount of 10-60 year 5 per cent sinking fund gold bonds was issued. The total capital stock of the United States Steel Corporation outstanding on December 31, 1903, was as follows: common stock, $508,302,500; preferred stock, $360,281,100.

The expenditures by all companies during the year for construction and additions to the property, less credits for property sold, equaled the sum of $31,042,135.97. Included in this total, however, are outlays amounting to $8,421,189.04 made on account of the furnaces, steel works, and mills of the Union Steel Company, and for the development of that company's coal, coke, and railroad properties, to which reference was made in the annual report for 1902. The balance of the expenditures, $22,620,946.93, represents outlays for additions and extensions to the various properties of other subsidiary companies. These expenditures comprehend only actual additions and extensions to the plants and properties.

The average number of employees in the service of all companies during the fiscal year 1903, in comparison with the fiscal year 1902, was as follows: 1903, 167,709; 1902, 168,127. The total annual salaries and wages paid amounted to $120,763,896 in 1903 and to $120,528,343 in 1902.

The number of stockholders of the United States Steel Corporation on the respective dates shown below was as follows: Preferred, February, 1904, 42,720; February, 1903, 31,799; increase, 10,921. Common, December, 1903, 37,237; December, 1902, 26,830; increase, 10,407. Totals, 79,957 and 58,629; increase, 21,328.

In accordance with the policy pursued by the Corporation since its organization substantial progress was made during the fiscal year last ended in the consolidation of its subsidiary interests. On April 1, 1903, The Carnegie Company, American Steel Hoop Company, and National Steel Company were merged under the

charter of the last named, the name being subsequently changed to Carnegie Steel Company. On the same date a merger was effected of the H. C. Frick Coke Company, McClure Coke Company, United Coal and Coke Company, South West Connellsville Coke Company, American Coke Company, and Continental Coke Company, the new company retaining the name of H. C. Frick Coke Company. Thus two corporate operating organizations replaced nine previously existing. On December 31, 1903, the interests of the American Tin Plate Company and the American Sheet Steel Company were united through the purchase by the latter of the property of the former. The name of the American Sheet Steel Company has been changed to American Sheet and Tin Plate Company.

The Union Steel Company properties acquired as of December 1, 1902, and which were fully described in the annual report for 1902, have been leased to various other subsidiary companies operating similar lines of manufacture, entailing no additional administrative expense.

On November 1, 1903, the United States Steel Products Export Company, whose stock is held by the Federal Steel Company, made arrangements to act as selling agent for all subsidiary companies. The result has been an increase in the export trade.

On December 31, 1903, the tonnage of unfilled orders on the books was 3,215,123 tons of all kinds of manufactured products, in comparison with a tonnage of 5,347,253 at the corresponding date in the previous year.

Occasionally publications are made concerning the affairs or earnings or results of the business of the Corporation, which are stated to be based on information derived from an " official," or " director," or " one identified with the Corporation," or " from inside sources." Obviously it would be inexpedient to undertake to contradict or explain statements of this kind, even though inaccurate and unreliable. From time to time information relating to the affairs of the Corporation is given out by the officials for publication; but it is the rule in such cases to accompany the statement with the name or office of the official making the statement, and no publication should be considered authoritative unless so identified.

# FERRO-SILICON MADE IN THE ELECTRIC FURNACE *

FERRO-SILICON made in the electric furnace can now be supplied as a sound and solid alloy, containing 50 per cent of silicon, without any tendency to disintegrate. The following six principal advantages are claimed for it over the ordinary alloy made in the blast-furnace; greater purity, economy in cost of carriage, storage, and handling; smaller quantity to produce the same silicizing effect; less cost per unit of silicon; less reduction of heat of molten metal on the addition of the ferro-silicon, and less time required for the amalgamation of the ferro-silicon with the molten metal, and consequently less consumption of fuel.

The following two tables give the typical analysis of the blast furnace alloy, in comparison with the electric furnace alloy:

| *Typical Analysis of Blast-Furnace Alloy.* | | *Typical Analysis of Electric-Furnace Alloy.* | |
|---|---|---|---|
| Silicon | 10.55% | Silicon | 51.80% |
| Iron | 83.16% | Iron | 46.13% |
| Carbon | 2.36% | Carbon | .15% |
| Manganese | 3.86% | Manganese | .08% |
| Sulphur | .03% | Sulphur | .003% |
| Phosphorus | .04% | Phosphorus | .057% |
| | | Aluminum | 1.61% |
| | 100.00% | | 99.830% |

A comparison between these figures is instructive. If it be required to add to any furnace charge as much silicon as is contained in one ton of blast furnace alloy, the impurities added at the same time are given by the corresponding percentages of one ton. But if the same quantity of silicon is required, and electric furnace alloy is used, the quantity of alloy needed is one-fifth of a ton, and therefore only one-fifth of the percentages of the impurities are added to the charge. Thus, we add, if using:

| *Blast-Furnace Alloy.* | | *Electric-Furnace Alloy.* | |
|---|---|---|---|
| Carbon | 2.36% of 1 ton | Carbon | .030 % of 1 ton |
| Manganese | 3.86% of 1 ton | Manganese | .016 % of 1 ton |
| Sulphur | .03% of 1 ton | Sulphur | .0006% of 1 ton |
| Phosphorus | .04% of 1 ton | Phosphorus | .0114% of 1 ton |
| | | Aluminium | .322 % of 1 ton |

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* "Electrochemical Industry," March, 1904.

The extra amount of iron added in the first case, which is regarded by some users as costing nothing, is an expensive economy, when confronted with the disadvantages inseparable from the introduction of its accompanying impurities, while, as regards price, silicon for silicon, there is no difference between them. Electric-furnace alloy costs about five times as much as blast-furnace alloy, and contains about five times as much silicon.

Steel. — When used in the manufacture of steel, whatever the process employed, the first effect of the silicon is to combine with any oxide of iron remaining in solution in the bath, and thus to prevent the formation of " red short " metal. Silicon thus added operates much more effectually than silicon left over from insufficient oxidation, whether by blast or otherwise — hence the desirability of using the purest possible alloy.

As it is silicon which operates to prevent oxide of iron remaining in the bath, it is preferable that whatever is added for this purpose should consist, as far as possible, of silicon, and nothing else.

The combustion of each kilogram of silicon produces 7,830 units of heat, i.e., each kilogram of silicon raises the temperature of 100 kilos of molten metal by about 300° Centigrade. White pig iron is not easily refined without ferro-silicon to serve as combustible. Electric ferro-silicon is practically suitable for the basic process, where it is added as the carbon is being boiled down, and where the metal is poured as rapidly as possible. Therefore, very little carbon being introduced, the operation of decarbonizing the steel is scarcely interfered with, the process is not prolonged, and the fuel saved.

On the contrary, if blast-furnace ferro-silicon be added, considerable carbon is introduced and also other impurities at a stage when in this process it is too late to get rid of them by combined boiling, itself involving greater fuel consumption.

Iron. — The operation of remelting cast iron tends always to increase the amount of combined carbon, and to reduce the graphite, thus rendering the iron whiter and harder at every melting.

The presence of silicon, which has greater affinity for iron than carbon, corrects this tendency, because it prevents the iron dissolving the carbon, and thus enables it to retain and even recover the softness due to the presence of a large proportion of graphite.

Generally speaking, the effects are: To render the casting more liquid, and therefore to take the molds more sharply — to render it sounder — to improve the quality of the iron, largely converting white iron into gray — to render it possible to use cheaper iron and more scrap — and when sufficient in quantity to increase the strength of the casting.

All these effects are due to the contained silicon. Therefore the more silicon there is in the alloy used, the greater is its effect.

Concerning the superiority of the 50 per cent electrolytic over the 10-15 furnace-made ferro-silicon, the results of one of the largest steel casting companies in America are of interest.

In the ordinary run of steel scrap, the practice is to use from 10 to 12 pounds of the silicon to a ton of the metal charged in the furnace. When the metal is of unusual good quality, this amount can be reduced. That, of course, is left to the judgment of the melter.

The advantage of this high grade silicon over the 10 per cent to 12 per cent is that it is not left in the furnace any length of time. The charge is made by throwing same right into the bath, and the heat is immediately tapped, the time consumed between time of charge of silicon and running of heat, being about 10 minutes.

The low grade silicon is banked on the inside of the charging door to thoroughly heat same, then pushed into the bath, even then causing it to chill more or less. It also takes longer to dissolve, thus causing a large percentage of the silicon to be burnt out. The high grade silicon also acts in the metal like aluminium, causing the metal to be very quiet, especially when the steel scrap is of a very rusty nature.

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## AN EXPLOSION OF HIGH-GRADE FERRO-SILICON *

### By G. WATSON GRAY, F. I. C.

(A Note read before the Faraday Society, Tuesday, February 2, 1904.)

EXPLOSIONS of any kind are to be regretted, but when they occur with comparatively new articles I venture to think it is desirable that such explosions should, without delay, be brought to the notice of Societies like the Faraday, so that the manufacturers may take steps to find the causes, and endeavor to remedy the

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* "The Electro-Chemist and Metallurgist," February, 1904.

same before the public mind has set itself against the article.   This is my excuse in asking your indulgence without longer notice.

On December 17th there arrived in Liverpool a consignment of high-grade ferro-silicon, which was detained on the quay owing to a fire having occurred on the vessel.   On January 12th, while being taken into warehouse, one of the iron drums exploded. The Fire Salvage Association then had it removed to a fireproof warehouse, where it was repacked into wooden kegs, but it still continued to explode.   On January 21st, one keg exploded, shattering the case, and throwing a man seven to eight yards away, necessitating his removal to the infirmary.

Those who brought the matter under my notice on the 13th considered the ferro-silicon, which had been produced in a carbide works, had got contaminated, and that the explosion was due to acetylene, but from the description given me, and the samples submitted, I was convinced that there was something out of the usual.   I, however, analyzed the samples, and only found such elements as I am accustomed to find in high-grade ferro-silicon. I then went to the warehouse with Superintendent Muir of the Fire Salvage Association and Inspector Jones of the Liverpool Explosives Department, and examined the gases in the casks by the Redwood and Clowes hydrogen flame apparatus.   The result was rather a surprise, although partly anticipated from the description given by those who had witnessed the explosion.   In addition to the hydrogen flame showing acetylene, dense white fumes were observed and a pronounced odor of arsenic felt.

I took some of the ferro-silicon from the cask that had exploded to my laboratory, where I boiled it in distilled water and collected the gases evolved.   These I examined, and found phosphoretted hydrogen and arseniuretted hydrogen.   The phosphorus existed in the greater proportion, but the amounts have not as yet been determined.   There is, I think, no doubt but that the explosions are due to the phosphorus, but the presence of a poisonous gas like arseniuretted hydrogen is very objectionable.

This is the first time I have heard of ferro-silicon exploding, and I have been acquainted with it from the experimental stages until the present.

# THE DETECTION OF THE FINISHING TEMPERATURES OF STEEL RAILS BY THE THERMO-MAGNETIC SELECTOR*

### By ALBERT SAUVEUR and JASPER WHITING

THE following few paragraphs from a recent paper † by one of us will form a proper introduction to this paper :

It is well known that when a piece of steel is allowed to cool undisturbedly from a high temperature, it crystallizes, and that the resulting crystals or grains, as they are frequently called, are the larger, the higher the initial temperature and the slower the cooling. This was first forcibly stated by Professor Tschernoff in his masterly paper on " The Manufacture of Steel and the Mode of Working It," communicated to the Russian Technical Society in April and May, 1868.

It is also well known that if steel be vigorously worked (rolled or forged) while it is cooling from a high temperature, crystallization is prevented, but as soon as work ceases crystallization sets in until a certain temperature is reached, which in the majority of cases is not far from 700° C., and below which there is no further growth of crystals.

We may, for convenience, call the range of temperature during which steel crystallizes, and which extends from the melting point to this critical temperature, the crystallizing range.

It follows from the above considerations that in working steel, as is done in the manufacture of so many implements, from a high to a much lower temperature, crystallization is retarded — i.e., is made to occur in a much shorter range of temperature, extending from the *finishing temperature* (i.e., the temperature at which work ceases) to the critical temperature. The resulting structure will, therefore, be finer grained — i.e., will be made up of smaller crystals — than if the metal had been allowed to cool *undisturbedly* from a higher temperature ; the crystals will be the smaller the lower the finishing temperature.

It has been conclusively shown that the finer the structure — i.e., the smaller the crystals — the more ductile will be the steel, and since ductility is always a very desirable property, whatever the intended use of the finished implement, we should so conduct our treatment of the metal as to confer upon it the finest possible

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structure. The importance of finishing steel implements at the proper temperature, therefore, need not be insisted upon. It is now appreciated by all enlightened metallurgists.

The manufacturers of steel rails have, more than any other producers of finished steel articles, given careful attention to the important influence of the finishing temperature upon the structure and the physical properties of their rails. In these days, when the tendency is to allow more and more carbon in rail steel, in order to lengthen the life of the rail, the importance of securing all the ductility possible from the heat treatment stands preëminently at the front.

It is quite certain that if a satisfactory means could be devised to ascertain whether or not rails are finished at the proper temperature, rail consumers would specify the application of such a test and would thereby obtain rails of a better and more uniform quality. It is well known to the readers of this paper that several methods have been proposed to this end, that they have been tried tentatively, but that none has proved satisfactory. Efforts have been made to determine the finishing temperature, (1) by the use of pyrometers, (2) by the shrinkage of the rails after leaving the finishing rolls, and (3) by the examination of the microstructure of the rails. The use of pyrometers naturally suggested itself at first as the most promising means of accomplishing that purpose, but it was soon found that no pyrometric device existed which could be applied in a practical way to the detection of the temperature of quickly moving rails. The control of the finishing temperature by the amount of contraction which the rail undergoes in cooling from the finishing to the atmospheric temperature is open to serious objections; they have been discussed before this Society and need not be reviewed here. Finally, the micro test, although attractive and useful, can only be applied to a very small percentage of the rails manufactured, and this is its greatest weakness.

A truly practical and efficient method of preventing the rolling of coarsely crystalline rails should fulfil the following requirements: (1) It should be continuous in its working — i.e., it should test *every rail;* (2) its working should be automatic; (3) it should not interfere with the speed or simplicity of the mill operations, and (4) the cost of its installation, maintenance and operation should not be excessive.

The method now to be briefly described appears to fulfil these requirements.

It is well known that when steel is heated to a high temperature it loses its magnetic properties — i.e., it ceases to be attracted by a magnet. On cooling the metal remains non-magnetic until a certain critical temperature is reached, when it regains its magnetism quite abruptly. In the case of medium high and of high-carbon steel this change in the magnetic properties occurs at the well-known point of recalescence, which also precisely marks the end of the crystallizing range. It is evident, therefore, that steel rails, in order to have a fine structure, should be magnetic when leaving the finishing rolls or should become magnetic shortly after leaving them, because this would indicate that they were finished but slightly, if at all, above the point of recalescence.

These considerations naturally suggest the application of a magnetic test to the control of finishing temperatures of steel implements, and this paper is merely a brief description of our efforts in this direction. Various methods of applying the magnetic test naturally come to mind. In order to be effective and practical, however, the mechanism should be automatic and actuated solely by the magnetic properties of the finished product. These automatic devices may be grouped into two classes:

1. The automatic separation of magnetic from non-magnetic rails, through the deflection of the magnetic rails, brought about (*a*) by the deflection of the magnetic rails themselves, due to the attractive influence of a magnet, or (*b*) by the motion of a suitable deflector placed in their path and which is controlled by the motion of a magnet, actuated in turn by the magnetic conditions of the rails. These two arrangements are indicated in a conventional manner in Figs. 1 and 2, respectively.* It will be evident that the magnetic device instead of being placed in close proximity to the rolls may be located at some other point, near the hot saws, for instance.

2. The automatic stamping of magnetic rails to the exclusion of others, or *vice versa*.

This method appears to us to be the more practical of the two, and it will suffice for the purpose of this paper to describe

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* Acknowledgment is made to the "Railroad Gazette" for the cuts used in this paper.

only that arrangement which, after careful study of the problem involved, has seemed to us to be the most promising.

The device illustrated in Fig. 3 consists of a rail-stamping machine of the usual design, arranged to place in the runway
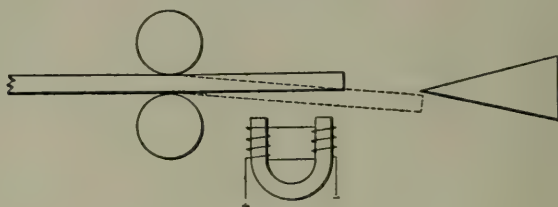


Fig. 1.

from the hot saws. The rails pass over two rollers keyed on to steel shafts extended back to the frame of the machine. To the rear of the frame is attached a steel keeper and bridge piece. This keeper is supported on a pin in such a way that if the two steel shafts become magnetized, it will be attracted and drawn down against the ends of the shafts. The tendency to magnetic attraction is resisted by a spring which serves the purpose of drawing the keeper away from the ends of the magnet as soon as the shaft ends forming the magnet poles become so weak as to have less influence on the keeper than the spring. The two solenoid spools are intended to be energized by means of an electric current, the connections of which are not shown. The action of the machine is as follows: When a rail which is cold
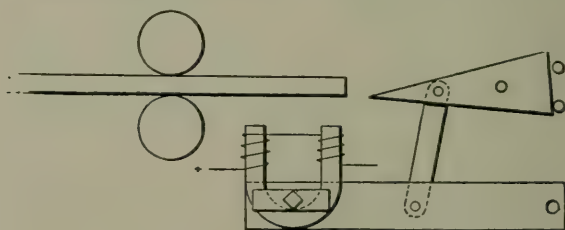


Fig. 2.

enough to be magnetic passes over the two rollers it closes the air gap between the rollers, and by the closing of this air gap the magnetic flux which is passing through the steel shafts, due to the current flowing in the solenoid, is increased many times. It will be seen that by thus connecting the two steel shafts by

means of a magnetic rail, a horseshoe magnet is formed with the poles at the rear of the machine. This increase in flux causes the keeper and bridge piece to be attracted, thus forming a complete magnetic circuit through the two steel shafts, the rail and the keeper. As soon as the keeper is attracted it closes the electric switch, which establishes a circuit through the electric motor, which in turn revolves the shaft carrying the stamp, thereby causing the stamping of the magnetic rail. The stamping mechanism is briefly as follows: The motor acting through the
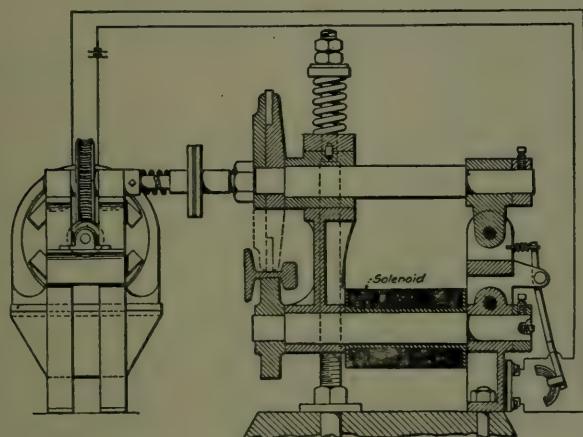


Fig. 3.

worm and gear revolves the shaft. The resulting movement of the die wheel brings the first character against the rail, after which the movement of the rail past the die wheel rotates the latter positively, until the last character passes out of engagement with the rail. The purpose of the friction clutch is to provide for differences in the relative speeds of motor and rail, and to permit the rotation of the shaft to come wholly under the control of the rail after the die has been brought into engagement with the rail through the medium of the friction clutch. As soon as the rail leaves the rollers the spring returns the armature to normal position, thus opening the circuit and stopping the motor. Rails which are finished too hot to be magnetic pass through without being stamped.

# SEMI-SOLID STATE IN METALS *

AT a recent meeting of the Staffordshire, Eng., Iron and Steel Institute, Thomas Turner, Professor of Metallurgy in the University of Birmingham, read a paper on "The Semi-Solid State of Metals," with special reference to the strength of pig iron and the heat treatment of steel. In the course of this paper he said:

"There is no sharp and clearly defined point at which a metal, in passing from the fluid condition, assumes all the characteristics of a typical solid. On the other hand, a solid, when near its melting point, retains or exhibits many of the properties of a liquid, including that of a considerable internal motion of translation within its own mass. It is only at temperatures relatively remote from their points of fusion that metals exhibit what are usually regarded as the characteristic properties of a typical solid.

When two or more metals are alloyed together, or when a non-metal is combined with a metal, a more complicated set of conditions is brought into play, and the question of equilibrium is more important.

Although lead, copper and iron have important applications in the commercially pure condition, the far more general use of metals is either when alloyed with one or more other metals, or in the presence of a non-metal, such as carbon, silicon or phosphorus. Such alloys or combinations may, for our present purpose, be divided into two groups.

1. Those in which the constituents, when melted, mix internally, and on cooling solidify together. In such cases we may have either a definite compound or eutectic; the latter is recognized microscopically by its banded or pearlitic structure.

2. Those in which the constituents, though intimately mixed or combined when melted, separate on cooling into two or more portions differing in fusibility. This is the usual case, and the portion which separates first is the excess of metal — such as iron, copper, gold, etc. — in a more or less pure state. The fusible portion is either the eutectic, or in special cases a product resulting from a mixture of the eutectic with a portion of the excess constituent. To this the name of sub-eutectic has been usually

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applied, but Professor Howe has recently suggested the more appropriate term of " eutectoid."

In many cases the fluid portion, containing carbide, silicide, phosphide, etc., is more brittle than the mass. Pure metals are usually seen under the microscope in irregular polygonal forms, and if the fusible brittle portion is separated on cooling as a sheath surrounding these metallic grains, the mass is brittle. With a larger proportion of impurities we usually have the fusible portion separated in the form of little segregations, or pockets. A familiar example of this is the case of phosphorus in cast iron. With moderate percentages the separated portion, rich in phosphorus, gives strength and rigidity to the mass. With too much phosphorus a eutectic separates in such quantity as to make the metal brittle.

It is scarcely necessary to insist upon the fact that in cases such as those just mentioned the mass does not solidify as a whole. It is, in fact, quite easy by heating lumps of cast iron, rich in phosphorus or sulphur, to obtain globules of extruded phosphide or sulphide without even so much as fusing the corners of the pieces which have been so heated.

It would be easy to multiply instances of important changes of structure which take place in metals or alloys at temperatures well below their melting points.

The interesting question now arises as to how far these general principles may be applied to the study of the properties of iron and steel. A little reflection will show their bearing upon many important facts. Probably the first suggestion will be that in casting a steel ingot we have segregation, and that this is an example of the semi-fluid state. Doubtless this is in a measure true, but there is this important difference, that in the ingot there is one portion fluid, while the other portion is more or less solid, and on subsequent analysis one part of the ingot is found to have quite a different composition from the remainder. When a large ingot solidifies we have a condition somewhat similar to the freezing of a pool of water, in which one part is ice while the rest is still liquid. It is necessary to distinguish segregation, or an actual separation in bulk, in which one part of the mass is solid and another part liquid, from the true semi-solid which is, so far as ordinary chemical analysis is concerned, of uniform composition throughout. In the latter case the differences in

composition are such as only microscopical, or other minute form of investigation, can determine. It is the second class of phenomena with which we are now concerned, and many such examples can be readily observed.

. The cementation processes for the production of steel, by heating wrought iron with carbon to about 900° C., is of considerable antiquity, having been very fully described by Réaumur in 1722. The action was at one time assumed to be due to the penetration of the mass by carbon monoxide, and to carbon transfer by a series of gaseous reactions. It was, however, proved by Roberts-Austen that pure carbon combined with pure iron when heated to redness in vacuo. The cementation processes must therefore be regarded as an example of molecular interpenetration at a temperature considerably below the melting point of wrought iron. Such penetration naturally becomes less marked as the temperature decreases, but it may be mentioned that, according to M. A. Colson, the mutual action between iron and carbon is still appreciable at 250° C. Such changes closely resemble diffusion as observed in liquids.

When pure carbon and iron are heated together, the molten iron is saturated when it contains 4.25 per cent of carbon. This composition is also stated to be that of the eutectic. The saturation point is raised by increase of temperature and in presence of manganese or chromium; it is lowered by aluminium and silicon. If cast iron which contains more than 4.25 per cent of carbon is allowed to cool, graphite will separate. On the other hand, cast iron containing less than 4.25 per cent of carbon will absorb more carbon if heated to a sufficiently high temperature in contact with that element. It is well known that slow cooling leads to the separation of carbon in the graphitic state with the consequent production of soft gray iron, while rapid cooling gives combined carbon and hard white iron. It has been very generally assumed, though perhaps not very definitely stated, that the separation of graphite occurs at the moment of solidification, and that when the metal is once solid no further changes can take place. Recent observations have, however, completely changed the views of metallurgists on this subject.

Ledebur first drew attention to the fact that there are two kinds of graphitic carbon in gray cast iron. One of these is the ordinary graphite which occurs in plates or flakes; the other is

much more finely divided, and from the fact that it occurs in annealed or "tempered" cast iron, Ledebur gave to this the name of "temper" carbon. For this same variety Howe has recently suggested the more appropriate name of temper graphite. To W. J. Keep, of Detroit, we are, however, indebted for the first clear indication of the difference in the method of production of these two kinds of graphitic carbon. Mr. Keep has definitely proved that the separation of graphite is not completed when the metal first assumes the solid state; but that such separation continues while the solid metal is cooling.

My own views on the separation of graphite may be briefly summarized as follows: At the moment of solidification graphite separates, chiefly in flakes or scales, which gives openness of grain and softness of texture. At lower temperatures carbon separates, chiefly as finely divided, or temper graphite, which gives softness, combined with closeness of texture and strength. All strong irons contain a considerable proportion of temper graphite, as will be shown by photomicrographic slides of specially strong irons, including the strongest iron (15.7 tons tensile) obtained in my silicon experiments of 1885. Silicon, in due proportion, not merely leads to the separation of graphite, but of graphite in the temper form, and hence to the production of strong iron. This separation takes place after the metal is solid, but while it is sufficiently soft to allow of expansion by the extended graphite; or while, in other words, it is in the semi-solid state.

Hitherto there has been no method in use for the determination of the size of the graphite in cast iron, though this is a very important question in connection with the strength and working properties of the material. A great deal of information on this point can be obtained by the use of the microscope, and by the comparison of a number of samples of known composition and properties under the same magnification.

It may be interesting here to note that the graphitic carbon obtained from cold blast pig iron is smaller than that obtained from ordinary hot blast varieties, and this fact very probably accounts for the closeness of texture and consequent greater value of cold blast iron.

Leaving cast iron, we may with advantage now take a brief glance at steel. If the semi-fluid state be again regarded as including the whole range of temperature during which the

internal flow or rearrangement is appreciable, it will be found that the lower limit of the semi-fluid state is about 100° C., since it is found that heating for a time in boiling water is sufficient for the tempering of certain kinds of hard steel. From this lower limit it extends to the melting point, or, say, 1,500° C. Somewhat below the melting point the semi-fluid condition becomes so marked that the different constituents in the steel segregate in a manner which is plainly revealed by the microscope, with the result that the steel becomes "burnt" and brittle. At intervening temperatures, as is well known, there are points of arrest in the heating or cooling curves, the position and number of which vary with the percentage of carbon and other elements; in some cases these show a very close analogy to what is observed with cast iron. Though the general principles are the same in either case, it must be remembered that in steel we are dealing not with the eutectic, but with the eutectoid or sub-eutectic, pearlite, which contains about 0.90 per cent of carbon. Steels which contain less than 0.90 per cent of carbon may be termed hypo-eutectoid, and those with more than 0.90 per cent hyper-eutectoid.

In addition to the more usual form of pearlite which is met with in normally cooled steel, there are at least two other varieties of the eutectoid which can be recognized easily under the microscope. On the one hand there is segregated pearlite, which is collected in patches and is coarse grained, and which is obtained by prolonged annealing. On the other hand, there is a uniformly distributed and exceedingly fine grained pearlite obtained by rapid cooling through the point $Ar_3$, or, say, about 870° C. This variety of pearlite is termed "sorbite."

Starting with pure iron, we have, as before mentioned, a polygonal structure revealed by the microscope. On adding a small quantity of carbon, say 0.10 per cent, it is observed that pearlite separates round the edges of the polygons, and as the proportion of carbon increases, the pearlite extends further and further into the grains of ferrite, until the granular structure disappears, and ultimately when, as before mentioned, the proportion of carbon reaches about 0.9 per cent, the whole area consists of pearlite. With further additions of carbon, cementite separates. At the present moment we are interested in these facts from the point of view of the semi-solid state, and it is obvious that no internal changes of structure which involve the entire

rearrangement of the particles of the mass, and which are accompanied by sudden expansion or contraction of the metal, can be possible except when the material is in a plastic condition.

We may regard the heated metal as being much in the condition of a sponge which has absorbed a certain amount of water, the condition of which may be affected by heat, pressure and other circumstances. The brittleness of a wet sponge when frozen, and its toughness when at ordinary temperatures, has many points of similarity to the cooling of a semi-solid metal containing a brittle eutectoid or other ingredient.

There is also a close analogy observed between the effect of the separation of graphite and of pearlite, in that with coarse grained or segregated pearlite we have a weak and soft material corresponding somewhat to soft gray iron, while finely divided and uniformly deposited pearlite gives increased tenacity, together with toughness and ductility, a combination which is of great importance for the majority of practical applications.

In conclusion, it may be observed as a result of the foregoing consideration of the physical and mechanical properties of copper alloys, of cast iron, and of steel, that the metals which are most commonly employed all exhibit evidences of the existence of a semi-fluid state, extending through a comparatively wide range of temperature, and we are forced, therefore, to conclude that when liquids solidify the solid does not at once assume all the properties which are associated with a characteristic solid such as, for example, a crystal of quartz, or a diamond, but that the cooling metal retains many of the properties of the fluid condition, which it only gradually loses as the temperature falls further and further from the original point of solidification."

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## THE WORLD'S IRON-ORE SUPPLIES *

### By BENNETT H. BROUGH
#### London

I N the first place I should like to express my indebtedness to the Council of this Institute for having invited me to come and give this lecture. I may say that I accepted your flattering invitation with a good deal of diffidence, because I remembered that in this city — and doubtless in my audience this evening —

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* Lecture delivered before the " West of Scotland Iron and Steel Institute."

there are a great many experts who are probably more familiar with the details of the iron-ore trade than I can possibly be. I, however, hope that if the views depicted in the lantern photographs I am about to show you are not altogether new to you all, yet they may be welcomed as giving rise to pleasant memories of past visits.

From time to time pessimistic paragraphs are published in the papers telling us that the Bilbao mines are worked out, that other sources of iron-ore supply have been secured by foreign competitors, and that the home mines are no longer productive. In view of the fact that in 1902 Great Britain consumed two million tons more iron ore than in the previous year, it may be of interest to inquire to what extent such statements are accurate, and to review briefly the present sources of iron-ore supply. The result will, it is believed, show that while it is true that the richest ores at Bilbao have been exhausted, and that more attention has been paid to calcination and to the washing of ores of inferior quality to enable them to meet market requirements, there need certainly be no immediate apprehension of a Bilbao-ore famine. Far-seeing British iron masters are, however, already making arrangements for the time when substitutes for the Bilbao iron ores will have to be found. And happily there are still large fields of ore almost untouched, in Spain and in other countries.

A study of the world's iron-ore mines presents points of great historical interest, inasmuch as the history of iron mining goes back far beyond the periods of authentic records. In Europe the rich ores of Spain and Elba were much used during the Roman period. Remains of the Roman working of iron mines have also been found in the Forest of Dean, in the Weald of Sussex, in Belgium, and in Austria. Indeed, the iron left in the slag heaps of the Forest of Dean furnished the chief supply to twenty furnaces for nearly 300 years. The ancient iron masters were unable to work any but the purest ores. The introduction of coal as fuel for smelting by Dud Dudley in 1618 and by Abraham Darby in 1713; the replacement of coal by coke; the invention of the modern steam engine by James Watt in 1770, of puddling by Henry Cort in 1784, of the hot blast by Neilson in 1828, of the Bessemer process in 1856, of open-hearth steel making in 1861, and of basic steel making in 1879, are a few of the great improvements that have stimulated the iron-ore mining

industry and have rendered it possible to work impure material. Indeed, improvements in the methods of mining and of smelting iron ores have followed in rapid succession, with the result that the world in 1902 produced no less than 43,475,000 tons of pig iron — the result of the smelting of 87,000,000 tons of iron ore. During the past half century the development of the iron industry has been remarkable. In 1854 Mr. J. K. Blackwell gave the following as the world's production of pig iron : —

|  | Thousands of tons | Per cent |
|---|---|---|
| United Kingdom, . . . . | 3,000 | 50.0 |
| France, . . . . . . . | 750 | 12.5 |
| United States, . . . . . . | 750 | 12.5 |
| Germany, . . . . . . . | 400 | 6.6 |
| Austria, . . . . . . . | 250 | 4.3 |
| Belgium, . . . . . . . | 200 | 3.3 |
| Russia, . . . . . . . | 200 | 3.3 |
| Sweden, . . . . . . . | 150 | 2.5 |
| Other countries, . . . . . | 300 | 5.0 |
| Total, . . . . | 6,000 | 100.0 |

In 1902 the world's production of pig iron was as follows : —

|  | Thousands of tons | Per cent |
|---|---|---|
| United States, . . . . . . | 17,821 | 41.0 |
| United Kingdom, . . . . | 8,679 | 19.8 |
| Germany and Luxemburg, . . | 8,403 | 19.3 |
| Russia, . . . . . . . | 2,521 | 5.8 |
| France, . . . . . . . | 2,427 | 5.6 |
| Austria-Hungary, . . . . | 1,430 | 3.3 |
| Belgium, . . . . . . . | 1,103 | 2.5 |
| Sweden, . . . . . . . | 538 | 1.2 |
| Spain, . . . . . . . | 350 | 0.8 |
| Canada, . . . . . . . | 319 | 0.7 |
| Japan, . . . . . . . | 24 | — |
| Italy, . . . . . . . | 31 | — |
| Total, . . . . | 43,646 | 100.0 |

The relative position of the iron mining industries of the

various countries is better shown by the following statement of
the world's output of iron ore in 1901 : —

|  | Thousands of tons | Per cent |
|---|---|---|
| United States, | 29,259 | 33.7 |
| United Kingdom, | 12,275 | 14.1 |
| Germany, | 12,115 | 14.0 |
| Spain, | 7,906 | 9.1 |
| Russia, | 5,797 | 6.6 |
| France, | 4,791 | 5.5 |
| Luxemburg, | 4,455 | 5.1 |
| Sweden, | 2,795 | 3.2 |
| Austria, | 1,894 | 2.4 |
| Hungary, | 1,634 | 1.8 |
| Newfoundland, | 738 | 0.8 |
| Greece, | 524 | 0.6 |
| Algeria, | 514 | 0.5 |
| Belgium, | 256 | 0.3 |
| Italy, | 232 | 0.2 |
| Bosnia, | 123 | 0.1 |
| Canada, | 70 | — |
| India, | 64 | — |
| Japan, | 64 | — |
| Australasia, | 26 | — |
| Norway, | 18 | — |
| Portugal, | 15 | — |
| Other countries, | 1,435 | 1.6 |
| Total, | 87,000 | |

It would be impossible in the limited time available to attempt
to describe even the main features of the long list of mines which
gave the United Kingdom in 1902 its 13,426,000 tons of iron ore
valued at £3,288,000. Even that enormous output did not meet
the consumption, and 6,898,000 tons were imported. Of that
amount 82 per cent was brought from Spain, 5.2 per cent from
Greece, 3.4 per cent from Algeria, 2.8 per cent from Italy (Elba),
1.6 per cent from Sweden, 1.4 per cent from Newfoundland, and
smaller quantities from France, Turkey, Germany, Portugal,
Russia, and Australasia. In fact, the world is being ransacked

for fresh iron-ore fields to supply rich ores for the British blast-furnaces. The harbor at which most of the ore was delivered was Middlesbrough (1,177,000 tons) ; then followed Glasgow with 919,000 tons ; and then Cardiff with 818,000 tons.

In Great Britain the principal iron-ore producing districts are Cleveland, in North Yorkshire, which in 1902 yielded 40.2 per cent of the total output of the kingdom ; Lincolnshire and North-amptonshire, yielding 26.7 per cent ; Cumberland, yielding 11.7 per cent ; Scotland, 6.2 per cent : and Staffordshire, 6.1 per cent.

The lecturer then proceeded, with the aid of lantern photographs, to describe the characteristic features of the principal iron-ore mines in Great Britain, United States, Spain, France, Russia, Austria-Hungary, Sweden, and other countries.

In conclusion, he expressed the opinion that whilst the rich ores of Bilbao and Elba are becoming scarce, there are still large quantities of ore available in the north of Scandinavia, in the south of Spain, in Algeria, Canada, Cuba, South America, India and China. The cost of carriage is, of course, an important factor, but the great economies which have been and will be effected in transport will reduce this item. The future of the home demand is likely to be affected by the development of the basic open-hearth process of steel-making, and there need be no immediate fear regarding the supply of the more impure ores suitable for that process.

# ABSTRACTS*

METALLOGRAPHY; or the Internal Structure of Metals. A. H. Hiorns. "Technics," January, 1904. 3,200 w. 12 photomicrographs. — The study of the internal structure of metals has received an immense impetus of late years from the application of the microscope to the examination of polished and etched specimens, which reveals the more intricate and ofttimes extremely minute variations in their internal architecture. It must not, however, be imagined that there is an essential difference between the microstructure and the ordinary structure, for there is only one structure in a given metal, although as a rule it is necessary to use a microscope to get the constituents sufficiently magnified for the eye to be able to perceive them. In many cases the structure is large enough to be seen with the naked eye, as in the case of the metals zinc and tin, and when this is not the case a pocket lens will often be found sufficient for the purpose. The use of the microscope in its application to metallurgy was first mentioned in 1722 by Réaumur, who described the structure of a chilled casting and traced the changes in the structure of softened cast iron as modified by the elimination of impurities. François again, in 1833, took the very interesting case of the direct reduction of iron from its ores, and followed the successive changes by the aid of the microscope. The following passage is full of interest, and might have been written by a worker of the present day. "If to these analytical

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data observations under the microscope, with a magnification of 300 to 400 diameters, be added, it is seen that ordinary iron is merely a metallic network with a close-grained tissue and submerged scoriaceous opaline, sometimes subcrystalline portions, with little globules and metallic grains arranged in every direction; sometimes nests of translucent prismatic and bacillary crystals, with metallic portions adhering, are noticed hidden in the paste; these are grains of steel which can be made to disappear by heating.

Until recently the applications of the metals to the arts and sciences have been based almost wholly on the results of chemical analyses and certain mechanical tests involving breaking strength and limit of elasticity. But chemical analysis can only partially determine the constitution and physical properties of complex bodies; it can take no account of the mechanical treatment the metal has undergone in the process of manufacture. Hammering, rolling, squeezing, drawing, annealing, etc., induce changes of structure which profoundly modify the elasticity and other physical properties, though they do not in the least change the ultimate chemical composition. The effects of impact, torsion, alternations of stress, and excessive strain, can only be fully appreciated when the changes of structure induced in the metals affected are fully known. In such cases the application of the microscope renders a most valuable aid in elucidating the source of these changes, inasmuch as it reveals to the eye the altered configuration of the constituent bodies.

The most important results of the microscopic investigation of metals have been obtained from the study of alloys for their physical constitution, which has an intimate connection with their physical properties. The alloy at present claiming chief attention is steel, with its great variety of structures, differing not only with each content of carbon, but also with that of other constituents, either adventitious or purposely added to produce a given effect. That the nature and arrangement of structure is by far the most important factor in determining physical properties is becoming more evident every day, and most of the researches of metallographists are conducted on this assumption, for it certainly enables one to explain many problems otherwise insoluble, such as the cause

of cracks, breakages, and other defects in samples of similar chemical composition.

Another illustration may be taken from the case of bearing metals, used for reducing friction. These alloys are found to consist of different constituents varying in hardness, and the load of the journal is carried through them by the hard component of the alloy, which is found to possess a low coefficient of friction, the plasticity of the matrix making it possible for the bearing to adjust itself closely around the shaft. The plasticity may be ascertained by means of a compression test, but the nature of the constituents must be determined by microscopical examination. On polishing such alloys on a yielding support, the softer portions are dug out while the hard parts stand in relief; bearing alloys, therefore, have a structure which is made apparent by the polishing process.

An impure metal or alloy is not generally a simple mixture of the metals, but the constituents enter into solution or chemical combination to form a number of distinct bodies which conjointly form the alloy, giving it its particular structure, and collectively determining its properties. We may thus consider the following cases: 1. Free metals in a pure state. 2. Solid solution of one metal in another. 3. Solid solution of one metal in the allotropic modification of another. 4. Chemical compounds in an excess of metal. 5. Solid solution of definite chemical compounds in each other. 6. Eutectic mixtures.

It will be seen from the above how complicated an alloy may be, what a great variety of modifications are possible, and how complicated the structure may be. To simplify the explanation we may consider the cases of a metal existing as an alloy in the free state, or as a chemical compound, or as a constituent body having its own melting point and other characteristics, but modified by the associations in which it exists. In the simplest form we have two components in such proportions as to be chemically united, yielding a uniform non-crystalline structure like glass or in such proportions as to be mechanically mixed without combination or separation, forming what is termed an " eutectic alloy," often having a more or less striated appearance, but of practically uniform structure throughout the mass. Either a pure metal, or a

chemical mixture, may separately exist in the general mass of an alloy. The mechanical mixture may be simply two metals, or a metal and a chemical compound; in either case it generally has a lower melting point than the metal in which it is diffused, and is therefore the eutectic or alloy of minimum fusion. If therefore an alloy consists of a metal and a eutectic, the former, on cooling, will solidify first, leaving the eutectic in the liquid condition, much in the same way as a salt, in crystallizing from a liquid solution, leaves behind a mass of mother liquor. The eutectic of an alloy is the mother liquor of a solid solution, and therefore forms the matrix or ground-work from which the other constituent has solidified. **No. 120. C.**

**Metallography.** O. Bauer. "Baumaterialienkunde," January 1 and 15, 1904. 7,200 w. — Metallography is the common name given to the science of the microscopic study of metals and their alloys. It describes not only metals and metallic alloys but deals also with solids and substances which while not having the properties of metals, form alloys or solutions with metals. Metallography has much in common with petrography and geology in its development and experiments.

Heyn gives the following as the province of metallography, to-day:

1. Description of the single elements in alloys, their determination, their chemical and physical properties, and their order of arrangements.

2. By determination of the changes in the kind and order of the elements caused by various treatments of the alloys (heating, chilling, working in form).

3. The determination of the changes in the internal structure which the substance, alloys or metal, undergoes when subjected to chemical or physical influences; here belong all the occurrences which are related to oxidizing, carbonizing, absorbing and similar chemical or physical occurrences, or to the phenomena of solution.

The study of the alloys of iron and carbon has developed a special branch of metallography for which von Jüptner has proposed the term "Siderography," and in the broader sense (illustrated above) Siderology.

The beginning of the nineties marks a turning point in metallographical research in several directions. Up to that time, with some exceptions, all investigators had in mind the search for new ingredients, their description and the completion of the technical part of metallography. Now an attempt was made to put into practical form what had been discovered, to make of use in practice the conclusions drawn from the investigations and at the same time to extend and advance the means of analytical and physical chemistry and physics. The investigators began their experiments now on the other metals and metallic alloys, and finally also on other substances. Metallography began to overstep the bounds set for it by its name "The Description of Metals." Ledebur's much contested theory that the alloys are to be considered as solutions of the metals, opened a path for itself, and the application of the theory of the saline solutions to alloys of metals in the liquid as well as in the solid state worked unusually successfully. The number of investigators in England, France, and America increased, while in Germany Martens and Wedding were still the only ones in the field.

J. O. Arnold came forward in 1890 with his work, "The Value of Microscopic Examination in Detecting the Incipient Fissuring or Pulling of Solid Steel Castings." Behrens, Howe, and Roberts-Austen have contributed much to the science. In 1896 the latter, associated with Osmond, published an interesting work on "The Structure of Metals, its Origin and Causes." From him also came the first complete curve of solidification of iron and carbon.

In 1893, A. Sauveur joined the ranks of the Metallographists, and his publications, "Microstructure of Steel," and later "The Microstructure of Steel and the Current Theory of Hardening" won for him recognition from the most important metallurgists, among them Ledebur, Osmond, and Roberts-Austen, and were translated into French. His magazine, "The Metallographist," is the central organ of metallography, the first and only magazine devoted to the interest of this branch of science. In it are published original works of the most important scholars, and reports and abstracts from the metallographical literature of other countries.

In 1894, Thomas Andrews and John E. Stead began work

in this new science. Andrew's experiments deal chiefly with flaws in steel. In 1893, at the Engineers' Congress in Chicago, where the results and observations of the investigators of this science were brought forward and compared, Stead's interest in the science was aroused, and he soon began his work, at first dealing with the technical side of metallography. Stead has used with great success the method of etching first proposed by Martens, for the purpose of detecting the presence of phosphorus in iron. His other work on the microstructure of iron and steel, and his remarks on the composition and structure of the other metals and their alloys have been important contributions to the science. Ledebur's work on alloys and his plan for teaching metallography, put into practice first in the Freiberg Mining Academy, have aided much the development of metallography.

Among the less important metallographists may be mentioned George Charpy, A. Le Chatelier, Jüptner, A. Stansfield, two Englishmen, C. T. Heycock and F. H. Neville, and a Frenchman, G. Cartaud. More work has been done in other countries than in Germany. Heyn, a pupil of Ledebur, at the Freiberg Academy has accomplished as much as any German. In all his work, he has made it his aim to put his knowledge into practical form.

The unexpectedly rapid development of this young science has aroused great hopes for its future, and how great and far reaching the results of work in this line will be cannot be prophesied. **No. 121. B.**

**The Microstructure of Steel.** "Engineering," February 5, 1904. 3,000 w. — The sixth report of the late Sir William Roberts was fully discussed at a meeting of the Institution of Mechanical Engineers, held January 29, 1904. Mr. J. E. Stead exhibited a diagram, reproduced below, which illustrates in a most striking manner the changes of structure taking place in steels containing varying amounts of carbon as they cool from a high to a low temperature. Mr. Stead spoke in part as follows:

"As shown in the diagram, the results were exaggerated, and were simply intended to illustrate the action that went on. The column on the left-hand side represented pure iron with

very large crystals; the second column steel with 0.25 per cent of carbon; in the further columns the carbon was 0.4, 0.6, 0,75, 0.95, and 1.4 per cent respectively. When bars of this character were heated at one end, so that the tops were at 1,000°, the other ends being left out in the air, there was obtained a complete gradation of change at a temperature from comparative coldness to 1,000° C. The bars represented in the diagram were heated in that way, and then taken out and quenched in water. The samples were then ground, care being taken not to heat them too much, and afterwards polished and etched; the result was that a structure such as that
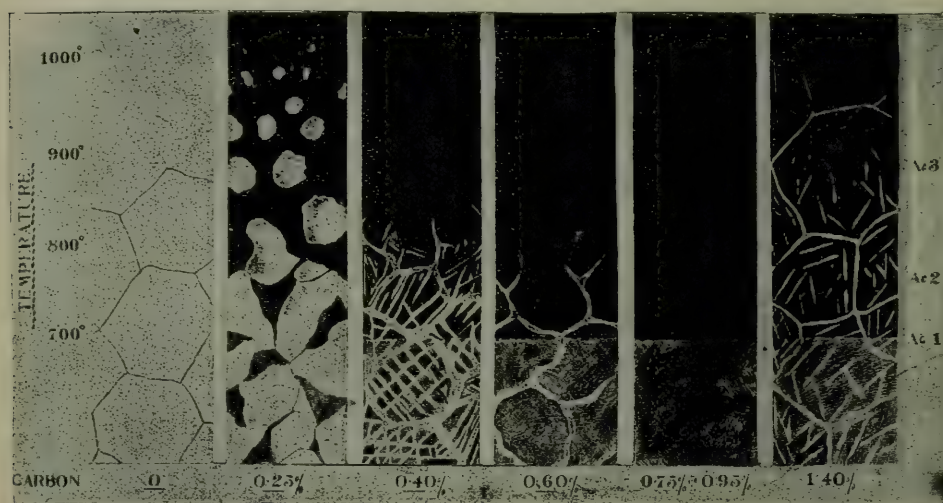


represented in the diagram was obtained. The diagram showed that when steel or iron with very large crystals was heated up to the critical point Ar₃ (about 870° C.), the whole structure was revolutionized; the coarse structure disappeared, and a fine structure took its place. When heated just a little above the critical point Ar₃ from being an exceedingly brittle structure — absolutely useless for any purpose — the metal became an excellent material. Referring to the next column, the speaker said that a different condition would be observed, carbon being present. He pointed out, further, that the junc-

tion line through the series of samples represented the point $Ar_1$ — the point at which recalescence took place on cooling; when quenched above the point $Ar_1$, hardenite was formed. There was no change in the free ferrite contained in steels until the temperature was raised to the point $Ar_3$, but before it reached that point the carbon in the dark pearlite areas was gradually diffused; when the temperature was raised to 1,000° C., the free ferrite had disappeared, and the carbon was completely diffused. If these steels had been allowed to cool down, they would have reverted to pearlite and free iron or ferrite; but, having been quenched, the carbon remained diffused. From this it would be understood what the authors of the report meant when they said it was necessary to heat to a certain degree in order to cause the diffusion or solution of carbon. In the lower carbon series it took a very much higher temperature to cause diffusion. He would point out that the pearlite in one case consisted of pearlite and cementite in thin laminae side by side. Passing to an example in which there was a much larger quantity of carbon, the cementite was found to be 5 per cent in excess of the saturation point; it was necessary to heat this steel highly in order to effect the complete diffusion of the cementite; the cementite dissolved in the martensite, and a homogeneous substance was obtained. The diagram showed that on quenching such steels from a high temperature, and reheating them at a temperature lower than was sufficient to cause the reformation of the band of pearlite, there would be obtained a very homogeneous steel, such as M. Osmond, Professor Gowland, and others had described as sorbitic, a term which Mr. Stead considered very convenient. **No. 122. B.**

**Silicon Steels.** Léon Guillet. " Revue de Métallurgie," Vol. 1, No. 1. 28 illus. 4,700 w. — This research embraces a very complete investigation of various alloys of iron and silicon. Two series of steels were prepared, one containing about 0.2 per cent and the other about 0.8 per cent of carbon. In each series the silicon varied from nothing to about 30 per cent. The actual contents of carbon and silicon are as follows:

| First Series | | Second Series | |
|---|---|---|---|
| Carbon | Silicon | Carbon | Silicon |
| 0.208 | 0.409 | 0.878 | 0.433 |
| 0.209 | 0.932 | 0.835 | 1.156 |
| 0.117 | 1.600 | 0.968 | 2.090 |
| 0.277 | 5.120 | 0.944 | 5.540 |
| 0.216 | 7.170 | 0.808 | 7.310 |
| 0.326 | 9.740 | 0.718 | 9.100 |
| 0.350 | 13.900 | 1.036 | 14.100 |
| 0.188 | 19.800 | 0.539 | 20.270 |
| 0.277 | 25.500 | 0.431 | 26.800 |
| 0.249 | 29.100 | | |

Steels of the first series exceeding 7 per cent silicon would not roll whilst a content of 5 per cent silicon and 0.9 per cent carbon represents the forging limit of the second series. From a micrographic study of the first series the author suggests a classification as follows: (1) Steels showing a pearlitic structure and containing from nothing to 5 per cent silicon. (2) Steels showing a special structure and containing more than 5 per cent silicon. This latter group may be sub-divided as follows: (a) Steels showing pearlite and graphite, these contain from 5 to 7 per cent silicon. (b) Steels containing the silicon in solution and the carbon entirely in the form of graphite. (c) Steels containing a definite compound of silicon and iron and the carbon in the form of graphite. These steels contain more than 20 per cent of silicon. A micrographic examination of the second series gives similar divisions. It is necessary then to conclude that only the content of silicon has an influence on the constitution of these steels and that the carbon has none. From a chemical study of the alloys it is concluded that silicon may exist in four states according to the amount present: (1) In a state of solution in iron, (2) $Fe_2Si$, (3) $FeSi$, (4) $FeSi_2$. The experiments on annealing show that silicon steels annealed at a temperature of 950° C. are affected in a similar manner to ordinary carbon steels, but if the annealing time is prolonged or the temperature raised the carbon is deposited as graphite: (1) The higher the content of silicon the lower the temperature at which graphite commences to separate. (2) The separation of graphite once commenced continues at temperatures lower than that at which the reaction started. Quenching experiments show

that silicon steels possessing a pearlitic structure undergo the same transformation as ordinary carbon steels, but silicon steels containing graphite appear to undergo no transformation by quenching. Only those steels which permitted of rolling were tested mechanically, and the results obtained from the first series are given in the following table:

| Carbon | Silicon | Elastic Limit | Tenacity | Elongation per cent | Reduction of Area per cent |
|---|---|---|---|---|---|
| 0.208 | 0.409 | 45.2 | 60.2 | 17 | 57.2 |
| 0.209 | 0.932 | 37.6 | 58.7 | 15 | 59 2 |
| 0.117 | 1.600 | 45.2 | 56.5 | 16 | 63.9 |
| 0.277 | 5.120 | 52.6 | 61.7 | 0 | 0.0 |

These results show that the elastic limit and tenacity are higher in the silicon steels than in carbon steels of the same carbon content; but these values do not sensibly increase with the content of silicon. Results obtained from the second series are as follows:

| Carbon | Silicon | Elastic Limit | Tenacity | Elongation per cent | Reduction of Area per cent |
|---|---|---|---|---|---|
| 0.878 | 0.433 | 62.5 | 115.2 | 5.5 | 10.4 |
| 0.838 | 1.156 | 62.5 | 103.9 | 4.5 | 10.4 |
| 0.968 | 2.090 | 76.8 | 105.4 | 3.0 | 0.0 |

These steels, again, have an elastic limit and tenacity superior to those of ordinary steels of the same carbon content. Further experiments on the mechanical properties of annealed and quenched steels are given, and of the latter the higher yield points and tenacities, compared with ordinary steels, are noteworthy. A further important feature is the high resistance offered to impact by quenched silicon steels, this property proving one of the most valuable of these steels.—"The Engineering Review," March, 1904. **No. 123. E.**

**Strength of Steel Castings at Ordinary and Higher Temperatures.** C. Bach. "Zeitschrift des Vereines Deutscher Ingenieure," March 12 and 19, 1904.—The experiments de-

scribed in this paper were undertaken to ascertain the dependency of the mechanical strength of steel castings on temperature; they are relative to castings from three different works, and are distinguished by the letters, *O, K* and *M* respectively. It is shown in the first place that the average tensile strengths will increase up to about 300° C.; the author does not note any appreciable influence of the duration of the load. For higher temperatures, on the other hand, the mean tensile strengths are found to increase, viz., for loads lasting about half an hour: For casting *O* from 4,788 (300° C.) down to 2,691 kg. sq. cm. (500° C.); *K* from 4,242 to 2,043 kg. sq. cm; *M* from 4,319 to 2,274 kg. sq. cm. For more prolonged loads (about 8 hours to 12 hours), there is a decrease in the tensile strength, namely, at 500° C.: For casting *K* from 2,043 down to 1,561 kg. sq. cm.; *M* from 2,274 to 1,911 kg. sq. cm. As regards, on the other hand, the individual values for the tensile strength, there are, in the case of casting *O*, the lowest departures at ordinary temperatures and the highest departures at 300 degrees, whereas in the case of *K* and *M*, 100 degrees and 20 degrees respectively will correspond with the minimum departures, and 200 degrees and 100 degrees with the highest departures. The average fracture tensions are found to decrease in the case of casting *O* from 25.5 (20° C.) down to 7.7 per cent (200° C.), *K* from 29.0 to 17.7 per cent, *M* from 27.2 to 15.2 per cent. For temperature upwards of 200 degrees, the average fracture tension will augment again up to 33.3, 51.3, and 26.1 per cent, respectively at the temperature of 600 degrees. Prolonged loads will result in the tension being lowered at 300 and 400 degrees, and augmented at the temperature of 500 degrees. The individual values for the fracture tensions show departures among one another, which augment in some cases at extraordinary rates, for increasing temperatures. The average contractions of the cross section are found to decrease up to 300 degrees, this decrease being: For casting *O* from 50.4 (20° C.) down to 15.8 per cent (300° C.), *K* from 56.1 to 49.4 per cent, *M* from 48.7 to 34.7 per cent. At higher temperatures there is once more an increase, values as high as 44.6, 75.7 and 42.1 respectively being noted at the temperature of 500 degrees. There is, moreover, an influence of a prolongation of the load. The departures

noted between the individual values are rather high. From the above it is inferred that a steel casting, while appearing to be a very satisfactory and fairly uniform material with respect to its tenacity at ordinary temperatures, may present little tenacity and uniformity at high temperatures. This behavior should have an important bearing on the construction of steam boilers, etc., where the strength corresponding to ordinary temperatures is less important than that corresponding to higher temperatures. **No. 124. B.**

**High Speed Tool Steel. Its Manufacture and Use.** " The Engineer," March 11, 1904. Ill. 4,500 w. — Paper read by J. M. Gladhill before the Coventry Engineering Society (England), March 4, 1904. The paper opens with brief descriptions of (1) the open-hearth, (2) the Bessemer, and (3) the basic open-hearth systems of producing steel, and then goes on to describe the method of manufacturing modern crucible steel. The working and treatment of high speed steel is then described at length. The author rightly concludes as follows: " Speaking for high-speed steel we must feel that we are only in the early stages of its manufacture and use, and that nothing approaching finality has been arrived at. When the steel maker looks at the innumerable alloys, of whose behavior and proportions when mixed with steel so much has yet to be learned, and also to the infinite number of combinations and percentages of those alloys with steel, and the corresponding varied results obtained, it is easily seen what a large field of research there is yet to traverse." **No. 125. B.**

**The Fracture of Metals under Repeated Alternations of Stress.** J. A. Ewing and J. C. W. Humfrey. " Phil. Trans.," 200A, 241 (1903). — The metal chosen for experiment was Swedish iron having a tensile strength of 23.6 tons/sq. inch and showing a proportionality of strain to stress up to 12 or 13 tons per square inch with no apparent defect of elasticity. When subjected to repeated reversals of a stress of 5 tons per square inch, no damage could be detected. With 7 tons signs of fatigue were noticed, though no cracks were formed within the limits of the experiments. With 9 tons the metal broke. This breaking is due to the appearance of slip-bands which

finally develop into cracks. The more frequent the reversals, the lower the breaking stress. Rest or heating to 100° causes a gradual healing.. W. D. B. "Journal of Physical Chemistry," February, 1904. **No. 126. E.**

**Notes on Cupolas and Cast Iron.** C. Morehead. "The Engineering Review," March, 1904. Paper read before the Rugby Engineering Society, January 21, 1904. — The author deals with varieties of cupola practice, giving analyses of cupola coke, and collating the results of various English and American experiments on cast iron. In experiments on the melting loss, it was found that rusty scrap melted alone gave a loss of 14 per cent, whilst the loss from good machinery scrap varied from 5 to 7 per cent. Mixtures of soft iron gave a loss of 4.87 per cent, whilst that obtained from hard cylinder mixtures varied from 2.5 to 3.6 per cent. **No. 127. B.**

**Limestone in the Cupola.** N. W. Shed. "The Foundry," April, 1904. 800 w. — The author favors the use of limestone to the extent of 15 per cent of the weight of the coke, or in common melting 40 pounds of limestone to each ton of iron. The advantages to be derived from the use of limestone are described as follows: (1) It absorbs sulphur from the coke, (2) it prevents a waste of iron, (3) it makes a good cover for the molten iron, preventing oxidation and (4) it makes a clean cupola. **No. 128. A.**

**Hardening and Tempering Steel.** "The Railroad Gazette," March 18, 1904. 6*. 1,280 w. — Abstract of a paper by Prof. A. Stansfield, read before the Canadian Railway Club, November, 1903. — The author describes the hardening and tempering of steel from the point of view of the constitution and microstructure of the metal. **No. 129. A.**

**Notes on Cupola Practice.** C. M. Schwerin. "The Foundry," April, 1904. 1,790 w. — Deals briefly with the lining of the cupola, starting of the fire, making up the charge, the temperature of the iron, the blast, coke, charging, etc. **No. 130. A.**

**The Value of Coke for Blast Furnaces and Foundries.** O. Simmersbach. "Stahl und Eisen," February 1, 1904. 4,500

w. — Influence of the strength, hardness, and porosity of the ash-, moisture-, and sulphur-content. Sample analysis of coke. **No. 131. C.**

**Proportions of Regenerative Gas Furnaces,** with Special Reference to Open-Hearth Furnaces. H. D. Hess. "Proceedings of the Engineers' Club of Philadelphia," January, 1904. Ill. 5,200 w. — A very able discussion of the various parts of regenerative furnaces, the refractory materials used in their construction, the gases, etc. **No. 132. E.**

**The Quality of Steel for Locomotive Boilers.** "Railway Age," March 11, 1904. 1,580 w. — Describes with comments the specification of the Master Mechanics' Association and of the American Society for Testing Materials relating to steel for locomotive boilers. **No. 133. A.**

**High-Speed Steels.** "American Machinist," March 31, 1904. 1,890 w. — Abstract of a paper presented by William Lodge at a recent meeting of the National Metal Trades Association in Philadelphia. **No. 134. A.**

**A New Rail Section.** "The Railroad Gazette," March 25, 1904. 1,180 w. 1*. — Describes with illustration a new rail section, the invention of Dr. Victor and Mr. Husham of Wiesbaden, Germany. **No. 135. A.**

**The New Tool Steel and Its Effect on Machine-Shop Methods.** Abstract of a paper by C. I. King in the "Wisconsin Engineer." "American Machinist," February 11, 1904. 2,000 w. **No. 136. A.**

**Fan Power for the Cupola.** T. D. West. "The Foundry," April, 1904. 1,150 w. — Paper read before the Pittsburg Foundrymen's Association, March 7, 1904. **No. 137. A.**

**Specifications for Bessemer Steel Rails.** Adopted by the American Railway Engineering and Maintenance of Way Association at its annual meeting at Chicago, March 16. "Engineering News," March 24, 1904. 900 w. **No. 138. A.**

**Instruction in Molding and Cupola Work.** Thomas D. West. "Journal of the American Foundrymen's Association," January, 1904. Ill. 2,580 w. **No. 139. H.**

**Foundry Costs — Their Analysis and Reductions.** Henry Hess. "Proceedings of the Engineers' Club of Philadelphia," January, 1904. 2,800 w. **No. 140. E.**

**Steel Castings.** C. W. Gennet, Jr. "The Railroad Gazette," February 26, 1904. 2,950 w. — Describes the manufacture, annealing and testing of steel castings. **No. 141. A.**

**Alumino-Thermics and Its Uses for Welding and Metallurgical Purposes.** "The Railroad Gazette," February 12, 1904. 1,450 w. **No. 142. A.**

**Foundry Formulae.** — A Plea for More. John F. Buchanan. "Journal of the American Foundrymen's Association," January, 1904. 1,850 w. **No. 143. H.**

**Special Jobs of Case Hardening.** E. R. Markham. "American Machinist," February 4, 1904. 750 w. **No. 144. A.**

**Casting Iron Around Steel.** E. H. Powell. "The Foundry," March, 1904. 2 ill. 800 w. **No. 145. A.**

**Surface Structure of Solids.** G. T. Beilby. Third Hunter Memorial Lecture, Glasgow, 1903. "Journal of the Royal Microscopial Society," February, 1904. 55 pages. 42 Photomicrographs. — From a series of experiments which he describes, the author draws the following conclusions:

1. The operations of cutting, filing, grinding or polishing produce on the surface of solids a thin film, which is in many respects essentially different to the general body underneath it.

2. This surface film results from a certain mobility, which is conferred on a thin layer of molecules by the tool or polishing agent moving over the surface.

3. While it is in the mobile condition, the film of solid molecules behaves like a liquid, and is subject to the action of surface tension.

4. If these propositions are established it will follow that a truly polished surface is one in which, for a certain minute depth, the substance has been liquefied and then smoothed by the action of surface tension.

5. Heat and solvents can confer on the molecules of solids sufficient mobility to enable their films or other minute portions of the solid to behave like a liquid.

6. In the aggregation of solids from their molecules there is a certain size of the aggregate up to which its form is controlled by surface tension, and only after this point is passed can crystallic force come into play.

7. The metals are the most opaque bodies we know, but their substance is nevertheless intrinsically transparent.

8. The "spicular" appearance frequently to be seen by the microscope on the surface of metals, and other solids under obliquely reflected light is due to a granular texture in the thin translucent film with which the surface is covered.

9. This granular texture results wholly or in part from the action of surface tension on the surface layer of molecules, while it is in the mobile condition. **No. 146. H.**

**The Testing of Cast Iron.** Richard Moldenke. Paper read before the New England Foundrymen's Association, February 10, 1904. "The Iron Trade Review." 2,530 w. — The author describes the influence of metalloids, of the quality of the pig iron and of the temperature and rate of cooling upon the properties of castings. He also considers the size of test bars and method of casting. **No. 147. A.**

**On the Microstructure of Metals and Alloys.** By William Campbell. "Electro-Chemical Industry," February, 1904. 4,830 w. — An able summary of our present knowledge of the microstructure of metals and alloys. **No. 148. B.**

**Labor-Saving Machinery in Foundry Operations.** By R. Moldenke. "Engineering Magazine," March, 1904. 4,881 words; numerous illustrations. — A very interesting article, describing with excellent illustrations the most important labor-saving appliances used in foundry work. **No. 149. B.**

**The Effort Developed in Drop Testing Nickel Bars.** (Sur les Efforts Développés dans le Choc d'Eprouvettes Entaillées.) A. Pérot. "Comptes Rendus," December 14, 1903. 800 w. — The article describes an automatic device for recording the work performed in testing specimens by the drop tests. **No. 150.**

# EDITORIAL COMMENT

**A. Ledebur**  Professor A. Ledebur was born in 1837 at Blankenburg, in the Harz Mountains. After attending the public schools of his native city, he spent two years (1855-1856) in the Harze Iron Works. His scientific education was obtained at the Technical School of Braunschweig. For thirteen years Professor Ledebur occupied different positions in various German iron and steel works, devoting much of his spare time to the writing of technical papers. In 1875 he accepted the professorship of metallurgy at the Royal Mining School of Freiberg, a position which he has occupied ever since.

Professor Ledebur, besides being the author of numerous papers, has written the following important books:

"Das Roheisen" (Pig Iron), 3d ed., Felix, Leipzig.

"Die Gasfeuerungen" (Gas Fuels), Felix, Leipzig.

"Handbuch der Eisenhüttenkunde" (Handbook of Iron Metallurgy), 4th ed., 3 vols., Felix, Leipzig.

"Lehrbuch der mechanischen metallischen Technologie" (Text-book of Mechanical-Metallurgical Technology), 3d ed., in preparation, Vieweg, Braunschweig.

"Leitfaden für Eisenhütten-Laboratorien" (Manual for Iron Metallurgical Laboratories), 6th ed., Vieweg, Braunschweig.

"Die Legierung" (Alloys), 2d ed., Krage, Berlin.

Professor Ledebur is a member of many scientific societies. The Iron and Steel Institute and the American Foundrymen's Association have elected him to honorary membership.

Professor Ledebur has been the recipient of many distinctions, conferred upon him in recognition of the eminent part he has taken in the progress of metallurgy.

**Sorbitic Steel**  Those of our readers who have read the excellent paper by J. E. Stead and H. W. Richards on Sorbitic Rails presented at the September meeting of the Iron and Steel Institute and reproduced in our January issue, must

have formed a correct idea of the nature of Sorbitic Steel. The production of this steel, however, has been described by many technical papers in such a way as to create the impression that a new steel had been discovered, or, at least, a new treatment resulting in the production of a metal hitherto unknown. As Mr. Boynton rightly says in his valuable article on Sorbitic Steel, published elsewhere in this issue, sorbitic steel rails have been produced for many years. Indeed it is doubtful whether any other but sorbitic steel rails have ever been rolled. Messrs. Stead and Richard's method merely consists in making the rails more sorbitic.

To obtain sorbitic steel it suffices to cool in the air a steel bar of relatively small cross section, from a temperature exceeding that of the critical point. Such treatment prevents the formation of true pearlite, retaining in its place the transition form which Osmond called sorbite, very slow cooling through the critical point being necessary for the formation of true pearlite. The sorbite formed under these conditions contains considerably more iron (ferrite) than pearlite and its structure is of a granular character while pearlite has the characteristic lamellar structure of eutectic alloys. Sorbite, and, therefore, sorbitic steel, possesses greater tenacity, and, according to Stead and Richards, better wearing quality than pearlite steel.

Sorbitic steel may also be produced (1) by quenching the metal in water at the end of its critical transformations, (2) by quenching it in oil from above the critical point, and (3) by quenching followed by suitable tempering. The latter method is the one used by Stead and Richards, their process consisting in superficially hardening the rail, which is then tempered by its own residual heat. It is especially, therefore, the outside of the rail which is thus made sorbitic.

Mr. Boynton in his paper clearly brings out a point of much interest to steel chemists. He shows that, as might have been expected, sorbitic steel contains more hardening carbon than pearlite steel, and since nearly all forged steels are more or less sorbitic, it follows that in order to obtain trustworthy results by the color carbon method, the samples should be carefully annealed, that is, made pearlitic, before being analyzed.

The improvements in the treatment of steel which these papers indicate, testify to the industrial importance of metallographic methods.

**The Production of Bessemer Steel in Special Converters** The total production of Bessemer steel in 1903 was 8,577,228 gross tons of 2,240 pounds, a decrease of some six per cent from 1902. This includes both ingots and finished castings. The totality of the ingot production was made, as usual, in standard Bessemer converters, but a portion of the castings was produced in special converters, including two Robert Bessemer plants, seven Tropenas plants and three plants with special surface-blown converters. The Tropenas process is the only one which has shown any vitality, starting with two plants in 1898, increasing to four in 1899 and to seven in 1900. In 1896 there were two Robert Bessemer plants, but these had been abandoned by 1898. Subsequently, however, the two which contributed to the 1903 production were built. No steel has been made by the Clapp-Griffith process since 1897, when the single remaining plant made a small production. A Walrand-Legenisel plant, built in 1895, was dismantled in 1897, and the process has not since been employed.

# IRON AND STEEL METALLURGICAL NOTES

**The Continuous Open-Hearth Steel Patent.** — In the contest over priority of invention of the continuous open-hearth steel process, the Court of Appeals of the District of Columbia has just rendered a decision, on appeal, which supports the previous award made by the Patent Office. The contest was between Ambrose Monell and Benjamin Talbot, each of whom claimed priority of invention. The court now holds that the evidence fails to show such priority of invention as was claimed by Mr. Talbot, and that the award of the patent to Mr. Monell must be confirmed.

The basal claim on which the patent rests is contained in the following count, which is taken from the specifications of the Monell patent: " 1. The method herein described of making steel, which consists in introducing into a basic open-hearth furnace iron oxide and lime and molten pig iron, substantially eliminating phosphorus from the iron while the iron is at a comparatively low temperature; withdrawing at an early stage, in the removal of carbon, the bulk of the slag containing the eliminated phosphorus, and heating the bath of metal and oxidizing the carbon until the carbon has been reduced to a point at which the metal is to be tapped."

Mr. Monell has a patent for the invention, issued to him on June 9, 1900, upon an application filed on March 10, 1900. His preliminary statement alleged conception of the invention by him on January 6, 1900; disclosure of it to others on the same day, and reduction to practice on February 1, 1900.

Mr. Talbot is the junior applicant. He did not file his application until December 6, 1900, which was six months after the issue of the patent to Monell; and he then took the claims and the specifications of Monell's patent and introduced them into his own application. His preliminary statement alleged conception of the issue by him about the year 1888.

disclosure to others about the middle of the year 1891, and reduction to practice in January of 1893.

After voluminous testimony taken on both sides, the several tribunals of the Patent Office concurred in awarding judgment of priority of invention to Monell; and from the judgment of the commissioner Talbot appealed. The case was taken to the court mentioned above, which is the special tribunal provided for such cases; and the decision disposes of the interference and establishes the Monell patent.

The litigation in this case has been protracted, and the patent is of considerable importance. Mr. Talbot is now resident in England, and much attention has been paid there to the process. A company has for some time been organized here to develop the Talbot inventions, the controlling interest being held by the Lackawanna Steel Company. Mr. Monell, who was engineer of the Homestead works of the Carnegie Steel Company at the time of his invention, is now president of the Orford Copper Company. — "Engineering and Mining Journal," February 11, 1904.

**Blast Furnaces as Gas Producers.** — The question has been raised of priority in the suggestion that iron blast-furnaces contained large possibilities in the contribution of power through the use of their gases to drive engines. In a paper by B. H. Thwaite read at the Glasgow meeting of the Iron and Steel Institute in 1901 the author called attention to the fact that as far back as 1894 he had suggesed that the blast-furnace might be made the center of cheap electric power supply areas. In 1896 he had followed this by proposing that under certain conditions the production of iron might become a secondary use of the blast furnace, the first place being given to providing power through its gases, this power being electrically distributed.

F. W. Lürmann, of Osnabrück, Germany, has called attention in this connection to the fact that in 1886 he had himself in a paper read before the Society of German Engineers, referred to the development in the near future of much larger gas engines than were then in vogue, driven by the internal combustion of producer gas and the waste gases of blast-furnace installations. The following is from a synopsis of the paper:

"Although the construction of the gas engine had made great progress in the last twenty years, yet the replacing of steam by gas was still far distant. When this was attained steam boilers would be unnecessary, and the gas produced direct from the fuel in generators could be used for driving engines. . . . By the application of generator gas of about the composition of 37 per cent carbon monoxide, 10 per cent hydrogen, and 53 per cent nitrogen, of which 1 cubic meter mixed with 1.27 cubic meters of atmosphere air develops, when burnt, 1,400 calories, and costs one-eighth of a penny, the gas engine would be considerably cheaper than any other motive agent. At blast-furnace plants with a good gas engine the waste gases, which contain half the coke still unburnt in the form of carbon monoxide, would be a far more efficient source of power than hitherto. Even these few particulars showed the interest with which each step in the development of the gas engine was attended for all industries." — "Iron Trade Review," March 3, 1904.

**Blast-Furnace Gas Power at Ilseder Iron Works.** — Until recently, the Iron Works at Ilseder, Germany, have employed part of the gas from the blast-furnaces, which produce 220 tons of iron per day, for raising steam which is applied in an electric generating plant of 1,830 H. P. Recently, Oechelhauser gas engines of 1,000 to 1,200 H. P. each have been installed, and the plant is designed for a total of 6,000 H. P. with facilities for extension to 12,000 H. P. The gas-driven blowing engines of 500 H. P., installed for trial purposes before transforming the whole plant, were found to use only one-fifth as much gas as was required for raising steam for the steam blowers. — "Electrical Review," London, December 4.

**Determination of Tungsten in Steel.** — E. Krahn proposes the following method for the determination of the tungsten content of steel ("Stahl und Eisen," January 1, 1904): Dissolve 2 grams of the material in a mixture of equal parts of sulphuric and phosphoric acids with three pints water. Add 3 c.c. of potassium permanganate solution from time to time while the steel is dissolving, and when cold divide solution into two portions. To one portion add 200 c.c. sulphuric

acid (1 to 3) and 40 grams zinc shavings, heat, and then allow
to cool in a current of carbon dioxide. Filter off any zinc
that remains and titrate with permanganate. In the second
portion the iron can be determined by the Reinhardt method,
or with stannous chloride and iodine, and the tungsten esti-
mated by difference. — "Engineering and Mining Journal,"
March 3, 1904.

**The Bessemer Converter in Basic Steel Making.** — Ac-
cording to the Cleveland "Iron Trade Review," experiments
were made last year at the basic open-hearth steel plant of
the Tennessee Coal, Iron & Railroad Company at Ensley, Ala.,
in which hot metal from the blast-furnaces was first blown in
a small Bessemer converter before being introduced into the
open-hearth furnace. The company recently completed the in-
stallation of a large converter, which is now in operation.
The hot metal from the furnaces is taken directly to the con-
verter and after the customary blowing process, in which
considerable silicon is burned out, is poured into the open-
hearth furnaces. Owing to the preliminary blow, it is expected
that the metal will take only about half the time in the
open-hearth furnace that used to be necessary for it to come
to steel of the desired analysis. Thus the open-hearth fur-
naces will have their output very largely increased. It is too
early at this writing to say much about the practical results
of the departure, as the tests have not yet been on a large
enough scale to make sure, but the preliminary reports are
highly satisfactory. — "Engineering and Mining Journal,"
March 10, 1904.

**Why Henry Bessemer was Knighted.** — It is almost the
universal impression that the late Sir Henry Bessemer was
knighted in recognition of the steel process which bears his
name, but such was not the case. The honor was bestowed
in 1878, when he was sixty-six years old, as a tardy reward for
a service rendered the British Government about the time
of his attaining his majority. The history of this, as told by
James Dredge, is that at the time when, in his early years,
Bessemer came into contact with some of the officials of
Somerset House, the seat of the Inland Revenue Department,

it was notorious that frauds on the government were per-
petrated to an alarming extent by the repeated use of stamps
affixed to deeds. It was estimated that an annual loss of
£100,000 was sustained from this cause, and to devise a means
for entirely putting a stop to this occupied Bessemer's atten-
tion. It is almost superfluous to say that he arrived at a solu-
tion by the simplest means, that of perforating the govern-
ment stamps, with dates. Now that this evident method has
found a hundred uses throughout the civilized world, to
safeguard stamps or cheques, and to divide postage stamps,
being among the most common, it is a little difficult to realize
the importance of this invention. To Bessemer it meant, in
anticipation, vast things, — assured fame, a retaining fee of
£600 a year as a government official, and a great advance
on the road to fortune. In reality, however, it meant nothing,
for though the invention was at once adopted, the official
promises were soon forgotten. — " Cassier's Magazine," April,
1904.

**The Bessemer Gold Medal.** — The Council of the Iron
and Steel Institute, on the motion of Sir Lowthian Bell, Bart.,
has resolved unanimously to award to Mr. Robert A. Hadfield,
chairman of Hadfield's Steel Foundry, the Bessemer gold
medal for 1904, in recognition of the great services he has ren-
dered to the metallurgy of iron and steel. The medal will
be presented in May next.

**The Newberry Charcoal Blast-Furnace.** — The charcoal
blast-furnace at Newberry, Mich., operated by the Michigan
Iron Company, surpassed all its previous records on February
29. On that day 87 tons of high grade charcoal pig iron were
manufactured. The furnace is 50 feet high by 10½ feet in
diameter at the bosh, and is therefore comparatively small.
This makes the record remarkable. The average production
of furnaces of this size is from 60 to 65 tons a day. — " The
Iron Age," March 17, 1904.

**Metallurgical Microscope.** — The accompanying illustra-
tion shows a metallurgical microscope by Watson and Sons
of London.

The foot is of the tripod pattern, and its front is so shaped that access is freely obtained to the milled heads, which control the movements of the stage and substage. The spread is 9⅝ inches. The instrument can be inclined on the foot in any position from the horizontal to the vertical; a clamping screw being provided for fixing it firmly in position. The



stage is mounted on a very substantial bracket which, at the back, is fitted by dove-tailed grooves into a frame in which, by rack-and-pinion, it can be raised or lowered to or from the body of the microscope. Special attention has been given to affording a sufficient interval between the nose-piece of the microscope and the surface of the stage, for the use of very low-power objectives. The coarse adjustment afforded

by the rack-and-pinion has, in many instances, been supplemented by a fine adjustment, so that the whole focusing of the specimen can be done from the stage instead of with the microscope body. Complete rotation is provided, so that specimens may be examined under every aspect of illumination. In the illustration it will be seen that a sliding bar is fitted to a recess in the stage, this bar may be instantly removed, and a leveling stage or a metal holder may interchange with it. The body is of extra large diameter, and is fitted with two draw-tubes, one having a rackwork, and the other sliding, so that a wide range of body-length may be obtained. This is sufficient range of adjustment for the focusing of the lowest-power lenses.—" Journal of the Royal Microscopical Society," February, 1904.

**Iron and Steel Institute Meeting.** — The following is extracted from circulars recently issued by the secretary. The annual meeting of the Institute will be held on Thursday and Friday, the 5th and 6th of May, 1904, at the Institution of Civil Engineers, London.

The proceedings of the first day will include the presentation of the Bessemer Gold Medal for 1904 to R. A. Hadfield, Vice-President, the announcement of the awards of the Andrew Carnegie Gold Medal and Research Scholarships for 1904, and some demonstrations of pyrometers suitable for metallurgical use.

The following list of papers is announced:

" On Pyrometers Suitable for Metallurgical Work," Report of Committee.

" On Coke Ovens," by C. Lowthian Bell (Middlesbrough).

" On Troostite," by H. C. Boynton (Harvard University).

" On the Range of Solidification and the Critical Ranges of Iron-Carbon Alloys," by H. C. H. Carpenter, M.A., Ph.D., and B. F. E. Keeling, B.A. (National Physical Laboratory).

" On Explosions Produced by Ferrosilicon," by A. Dupré, Ph.D., Chemical Adviser to the Explosives Department, Home Office, and Captain M. B. Lloyd, R.A., H. M. Inspector of Explosives.

"On the Thermal Efficiency of the Blast-Furnace," by W. J. Foster (Darlaston).

"On the Production and Thermal Treatment of Steel in Large Masses," by Cosmo Johns (Sheffield).

"On the Manufacture of Pig Iron from Briquettes at Herräng, Sweden, by Professor H. Louis, M.A., Assoc. R.S.M. (Newcastle-on-Tyne).

Reports on research work carried out during the past year will be submitted by C. O. Bannister (London), by P. Breuil (Paris), by K. A. Gunnar Dillner and A. F. Enström (Stockholm), by J. C. Gardner (Middlesborough), by F. H. Wigham (Wakefield), by A. Campion (Cooper's Hill), and by P. Longmuir (Sheffield), Andrew Carnegie Research Scholars.

Annual dinner of the Institute will be held in the Grand Hall of the Hotel Cecil on Friday, May 6, under the presidency of Andrew Carnegie.

**The American Meeting of the Iron and Steel Institute.** — According to the Bulletin of the American Iron and Steel Association, Mr. John Fritz of Bethlehem, who is a Bessemer medalist and an honorary member of the Iron and Steel Institute, is president of the reception committee which is to receive the visiting members of the Institute at their October meeting this year in New York, and that the executive committee is constituted as follows: Chairman, Charles Kirchhoff; treasurer, Robert E. Jennings; secretary, Theodore Dwight.

**Damaskeened Steel.** — Professor Tschernoff calls our attention to the nature of damaskeened steel. The metal contains pearlite, and an excess of cementite, which, owing to extremely slow solidifications and subsequent cooling, segregates in a very marked degree. To this slow cooling he attributes the beautiful designs seen on damaskeened blades.

The appearance of these blades recalls the structure of pearlite. Shall we infer from it that the extremely slow cooling, referred to above, has developed pearlite on so large a scale that it can be readily seen with the naked eye? In other words, that the metal is made up of large, undulated plates alternately of ferrite and cementite, to which it owes the pearly and wavy appearance of its surface?

# REVIEW OF THE IRON AND STEEL MARKET

The improvement in the iron trade which began early in the year and was rapid during March appears to have terminated, leaving the condition about midway between the extreme depression in 1893-4 and the extreme prosperity from 1899 to 1902. On this level the trade is likely to rest for some time, perhaps for years, with occasional wavers.

The American iron trade depends upon three great classes of buyers: the railroads, all other domestic consumers, and foreign buyers. The approximate level in these three classes of trade has been found approximately for some time to come, with poor buying by railroads, excellent buying by other domestic consumers, and a moderate amount of export business which could only be increased at the expense of trading without profit or possibly at a loss.

The absence of good railroad buying prevents any high degree of prosperity being reached. With the continued increase in operating expenses the heavier business done by the railroads does not allow as much as formerly for improvements, and the prospects of floating additional securities are not good.

It appears therefore that the iron trade has entered upon a period closely comparable with that from 1884 to 1892, during which business was currently reported as being not altogether satisfactory, although in retrospect during the immediately following years this period appeared by comparison very good.

Current production of pig iron has now approached within a few per cent the average of eighteen million tons a year as shown by the statistics of both 1902 and 1903, but this showing is less favorable than would appear on the surface. During those years it reached a rate for some months of close to twenty million tons annually. Since this maximum was passed there has been added, including those operations at Buffalo by a steel works and merchant furnace interest which will certainly be completed this year, between two and two and a half million tons

annually of pig-iron capacity and over a million tons annually of steel capacity. These are conservative figures. The new capacity will be operated at the expense of the old, representing, on a continuance of the present production rate, an excess, roughly, of four million tons of pig-iron capacity and two million tons of steel capacity. Necessarily competition will be keen, operating costs will be closely scrutinized, and the greatest effort made to reduce costs in all directions.

*Pig Iron.* — Prices have remained about stationary at the advances scored during March: At valley furnace — Bessemer, $13.50 to $13.75; No. 2 foundry, $13.25 to $13.50; forge, $12.50. At Pittsburg — Bessemer, $14.35 to $14.60; No. 2 foundry, $14.10 to $14.50; forge, $13.25 to $13.50. At Philadelphia — No. 2 foundry, $15.00 to $15.25; standard forge, $13.50 to $14.00; basic, $14.00 to $14.25. At Chicago — (northern iron) No. 2 foundry, $14.00 to $14.50; malleable Bessemer, $14.00 to $14.50; Lake Superior charcoal, $15.25 to $15.75. At Birmingham — No. 2 foundry, $9.75; basic, $9.00; forge, $9.00; freight from Birmingham to Chicago, $3.85; to Pittsburg, $4.35; to New York, $3.25.

*Steel.* — Billet association prices were reaffirmed on April 6th and are strictly maintained, with occasional slight premiums on small lots for very early shipment: delivered Pittsburg, Wheeling, valleys, Johnstown, Ashland and Lorain, $23.99; Cleveland, $23.50; Chicago, $24.00; Philadelphia and Baltimore, $24.25; New York, $24.75; New England points, $25.25. These prices cover Bessemer and open-hearth billets 4 × 4 and larger, 0.25 per cent carbon and under; small billets and sheet bars, long lengths, are $1.00 extra, and shearing to specifications 50 cents additional.

*Merchant Bars.* — Bessemer steel, 1.35 cents; open-hearth steel, 1.40 cents, both in carload and larger lots, f.o.b. Pittsburg plus freight, half extras; common iron, about 1.35 cents, Pittsburg, half extras, plus freight.

*Plates and Shapes.* — Tank quality plates and beams and channels 15-inch and under, 1.60 cents, Pittsburg.

# STATISTICS

**The World's Pig Iron Production.** — In our issue of last January we presented a table of the production of pig iron in the world in 1902. Since then statistics for 1903 have come to hand from the important countries, and reducing all to gross tons of 2,240 pounds we have the following comparisons:

|  | 1902 | 1903 |
|---|---|---|
| United States . . . . | 17,821,307 | 18,009,252 |
| United Kingdom . . . | 8,517,693 | 8,811,204 |
| Germany and Luxemburg | 8,269,700 | 9,926,251 |
| France . . . . . . | 2,389,000 | 2,782,986 |
| Belgium . . . . . . | 1,053,000 | 1,197,275 |
| Sweden . . . . . . | 516,110 | 481,961 |
| All other countries . . . | 5,008,190 | 5,008,190 |
|  | 43,575,000 | 46,217,119 |

No attempt is here made to make a fresh estimate of the production of "other countries." Canadian statistics show a decrease of 54,000 tons, but Mexico, which does not return accurate statistics, would undoubtedly show an increase to more than offset this. The production in 1900 barely exceeded 40,000,000 tons. Belated returns may be expected from Russia and Finland, with a trifle under or over 3,000,000 tons, Austria-Hungry, with between 1,000,000 and 2,000,000 tons, and Spain and Italy with less than 500,000 tons between them. The rest of the world probably produces less than 100,000 tons.

**British Iron and Steel Production in 1903.** — The British Iron Trade Association has just made its returns of production in 1903, from which we make the following comparisons with 1902, in tons of 2,240 pounds:

### Pig Iron

|  | 1902 | 1903 |
|---|---|---|
| Forge and foundry | 3,727,294 | 3,875,826 |
| Hematite . . . | 3,683,148 | 3,760,422 |
| Basic . . . . | 922,218 | 991,610 |
| Spiegeleisen, etc. . | 185,033 | 183,346 |
| Totals | 8,517,693 | 8,811,204 |

### Open-Hearth Ingots

|      | Acid      | Basic   | Total     |
|------|-----------|---------|-----------|
| 1900 | 2,862,566 | 293,484 | 3,156,050 |
| 1901 | 2,939,614 | 351,177 | 3,290,791 |
| 1902 | 2,676,508 | 406,780 | 3,083,288 |
| 1903 | 2,613,274 | 510,809 | 3,124,083 |

### Bessemer Ingots

|      | Acid      | Basic   | Total     |
|------|-----------|---------|-----------|
| 1900 | 1,253,905 | 491,101 | 1,745,004 |
| 1901 | 1,115,985 | 490,268 | 1,606,253 |
| 1902 | 1,157,380 | 668,399 | 1,825,779 |
| 1903 | 1,316,915 | 593,103 | 1,910,018 |

The total production of ingots by both processes in 1903 was 5,034,101 tons, the best year on record, but only slightly exceeding 1900 and 1901, which held records in their times with a trifle over 4,900,000 tons.

**The Manufacture of Open-Hearth Steel in England.—** The " Iron and Coal Trades Review " for February 12, 1904, publishes the following interesting information concerning the production of open-hearth steel in England in 1903.

Analyzing the figures for last year, it appears that there are about 94 firms engaged in making open-hearth steel either for rolling or for casting. These firms have 512 furnaces, and the following table shows the number of furnaces in each district and distinguishes between acid and basic bottoms:

|                              | Firms | Acid Furnaces | Basic Furnaces |
|------------------------------|-------|---------------|----------------|
| Scotland                     | 17    | 120           | 17             |
| Northeast Coast              | 14    | 96            | 21             |
| South and North Wales        | 24    | 91            | 16             |
| Sheffield and Leeds          | 22    | 66            | 10             |
| Lancashire and Cumberland    | 9     | 31            | 7              |
| Staffordshire, etc.          | 8     | 13            | 24             |
|                              | 94    | 417           | 95             |

One of the first facts that stand out in the above table, is the increasing number of furnaces working on basic bottoms. Roughly the proportion is four acid bottoms to one basic one.

This is a very different proportion to that of Germany, where out of a total of 335 furnaces 265 are basic; but the proportion of basic furnaces in Great Britain is much higher that it was five years ago.   So far the basic process has not made much headway in the Middlesborough district, with the exception of Messrs. Dorman, Long & Company's Works.   In Scotland, the Lanarkshire Steel Company is the only large maker of basic steel, but in Staffordshire we find that practically all the larger firms are using basic linings.

There are 229 furnaces of 20 to 30 tons capacity, there being almost double as many with these limits of size as those of any other size.   There are 118 furnaces of 30 to 40 tons capacity, and 64 furnaces of 50 tons or over.   The majority of these are, of course, 50-ton furnaces, but there are the Talbot and Bertrand-Thiel furnaces at Frodingham, Cardiff, Cargo Fleet, Brymbo, Round Oak, and Port Talbot.   Practically all the other large furnaces are either in Scotland or the North of England.   Of furnaces from 10 to 20 tons capacity there are 58, and there are 48 furnaces of under 10 tons capacity.   In the Sheffield and Leeds district there are few furnaces over 30 tons capacity, 54 furnaces out of the 76 in the district ranging from 10 to 30 tons.   In the Middlesborough district, however, 60 furnaces out of 117 are over 30 tons, and 97 of the furnaces are over 20 tons.   In Scotland, 57 furnaces are over 30 tons, and 124 furnaces out of a total of 137 are over 20 tons.   The following table summarizes the capacities for the different districts:

|  | 1 to 5 tons | 5 to 10 tons | 10 to 20 tons | 20 to 30 tons | 40 to 50 tons | 50 tons and over |
|---|---|---|---|---|---|---|
| Scotland . . . . . . | 2 | 5 | 6 | 67 | 36 | 21 |
| Northeast Coast . . . . | 6 | 6 | 8 | 37 | 26 | 34 |
| South and North Wales . . | 1 | 9 | 6 | 61 | 29 | 5 |
| Sheffield and Leeds . . . | 2 | 4 | 26 | 28 | 15 | 1 |
| Lancashire and Cumberland | 3 | 6 | 3 | 16 | 8 | 2 |
| Staffordshire, etc. . . . . | 1 | 2 | 9 | 20 | 4 | 1 |

Expressed in percentages there are 12 per cent of furnaces 50 tons and over; 23 per cent range from 30 to 40 tons; 44 per cent from 20 to 30 tons; 11 per cent from 10 to 20; 6 per cent from 5 to 10; and between 3 and 4 per cent of 5 tons and under.

**Pig Iron Production in Germany.** — The 1903 pig iron production of Germany (including Luxemburg) was as follows, in metric tons of 2,204.6 pounds:

| | |
|---|---:|
| Foundry iron | 1,798,773 |
| Bessemer iron | 446,701 |
| Basic iron | 6,277,777 |
| Spiegeleisen, etc. | 703,130 |
| Forge iron | 859,253 |
| Total | 10,085,634 |

The geographical division was as follows:

| | |
|---|---:|
| Rhenish provinces and Westphalia | 4,009,227 |
| Siegen, Lahn and Hesse-Nassau | 718,106 |
| Silesia | 753,053 |
| Pomerania | 134,770 |
| Hanover and Brunswick | 357,779 |
| Bavaria, Würtemburg and Thuringia | 159,403 |
| Saar | 735,968 |
| Luxemburg and Lorraine | 3,217,328 |

It is of course to be noted that in Germany Sir Henry Bessemer is only credited with the invention of the pneumatic process as employed with an acid lining; what in England and the United States is denominated the basic Bessemer process is in Germany called the Thomas-Gilchrist, hence the Bessemer pig iron referred to above is substantially the same as Bessemer iron in the United States, while what is denominated basic iron is intended largely for the basic Bessemer process, and not, as in the United States, for the basic open-hearth.

**The British and German Iron and Steel Trades.** — " The Engineer," February 12, 1904. A comparison of the British and German iron and steel trades at the present moment shows the remarkable fact that the latter has now eclipsed the former, and that in the short period of six years Germany has doubled the tonnage of her exports, and increased the value beyond that of the United Kingdom. It was known that the production of pig iron, as was stated in this journal on October 16th, 1903, under the title of " The Steel Trade Supremacy," would exceed the British output in 1903. The actual figures for Ger-

many are 10,085,634 tons, as compared with 8,402,660 tons in 1902, whereas the estimated production of pig iron in Great Britain during last year amounts to 8,350,000 tons. It was, however, scarcely anticipated by British iron and steel firms that the extraordinary progress of the German export trade in iron and steel, and iron and steel manufactures, during 1902 would be continued in 1903, but this expectation has not been verified by the results, although the proportionate rate of development is considerably less than that which took place in 1902. In metric tons the exports from Germany, which only totaled 1,626,130 tons in 1898, advanced to 2,347,211 tons in 1901, and 3,309,007 tons in 1902, while a further increase to 3,480,000 tons occurred in 1903. These figures compare with the British exports of iron and steel, which reached 3,571,373 tons in 1903, as against 3,473,645 tons in 1902, and 2,812,523 tons in 1901. It will be seen that if material progress had not also been made by the United Kingdom in the past two years, the Teutonic exports would have surpassed those of this country.

If the position of affairs is regarded from the standpoint of the value of the exports, it will be found that Germany has already outstripped the United Kingdom, and this may be attributed to the fact that the former has already begun to sell to other countries a larger tonnage of semi-finished and manufactured iron and steel than was previously the case. According to the Board of Trade returns, the value of the British iron and steel exports amounted to £28,877,337 in 1902, whereas that of the German exports reached £30,169,000. The figures for the United Kingdom are £30,453,190 for the past year, while the provisional ascertainment officially made in Germany is represented by £32,912,500. The latter total is subject to future correction, but bearing in mind the actual difference between the provisional and the ascertained values in 1902 and the condition of prices during 1903, it is highly improbable that for the latter year the final results will be found to be less than £32,000,000. If this assumption should prove to be correct, the value of Teutonic exports will have exceeded that of the British exports by over £1,500,000 in 1903, as compared with a realized excess of £1,291,663 in 1902. When the question of imports is taken into consideration, it will be seen that

Germany buys considerably less from other countries than the United Kingdom. The total British imports of iron and steel amounted to 1,320,586 tons in 1903, 1,040,744 tons in 1902, 868,739 tons in 1901, and 761,402 tons in 1900. On the other hand, Germany imported only 315,898 tons in 1903, 268,918 tons in 1902, and 400,982 tons in 1901; while in the three years of the high period of prosperity the purchases amounted to 983,112 tons in 1900, 839,839 tons in 1899, and 528,808 tons in 1898. The above figures constitute remarkable evidence of the development of the German export trade, upon which all eyes are at present turned in the hope of further extending the external markets.

The increase in the volume of the exports from Germany during 1903 would have been greater had it not been for the decline which took place in the middle of the summer, notably in the case of orders for the United States, and which continued to the end of the year. As, however, the American demand ceased several months ago, and is not likely to recur within a considerable period, it is probable that considerable difficulty will be experienced in maintaining the export trade this year on the same level as in 1903, but this question depends to a large extent upon the success or failure of the long pending scheme for the formation of a steel trust or syndicate, the fate of which has not yet been finally decided. Among the German exports in 1903, large increases may be mentioned as having taken place in pig iron, angles, etc., rails and accessories, blooms and billets, plates and sheets, wire, castings, and tubes. The German official returns show that among other exports that country forwarded to the United Kingdom 152,-787 tons of angles, etc., in 1903, as compared with 121,659 tons in 1902; 390,613 tons of blooms, etc., as against 362,917 tons; and 64,249 tons of rails as against 54,826 tons in 1902. Thus, in three classes of products the exports to the United Kingdom reached the formidable total of 607,649 tons last year. It is, therefore, little wonder that on the one hand British producers are loud in their lamentations at the continued invasion of foreign steel, but on the other hand the shipbuilders and sheet rolling mills have been glad to purchase at the lower prices at which the German articles have been offered.

**Pig Iron Production in Canada.** — The American Iron and Steel Association ascertains the Canadian pig iron production in 1903 to have been 265,418 long tons of 2,240 pounds, against 319,557 tons in 1902, 244,976 tons in 1901 and 86,090 tons in 1900. Of the 1903 production 126,892 tons were basic, while less than 1,000 tons of Bessemer was made. Charcoal was used in the smelting of 17,513 tons of the total. It was not until 1901 that the Canadian pig iron production attained the dignity of requiring six figures for its expression.

**French Iron and Steel Production.** — From the recent report of the Comité des Forges de France we take the following figures of production referring to metric tons of 2,204.6 pounds:

|  | 1902 | 1903 |
|---|---|---|
| Foundry pig iron . . . . | 419,543 | 569,239 |
| Total pig iron . . . . . | 2,404,974 | 2,827,668 |
| Bessemer steel . . . . . | 959,097 | 1,172,984 |
| Open-hearth steel . . . . | 609,206 | 681,636 |
| Total steel . . . . . . | 1,568,303 | 1,854,620 |

**Swedish Iron and Steel Production.** — The Swedish Iron Manufacturers' Association has collected statistics for 1903, from which we compile the following table, showing the production in metric tons, together with the number of blast-furnaces, puddling furnaces, Bessemer converters and open-hearth furnaces in operation in the respective classes of production:

|  | 1902 | | 1903 | |
|---|---|---|---|---|
|  | Tons | Number | Tons | Number |
| Pig iron . . . . . | 524,400 | 119 | 489,700 | 98 |
| Iron blooms . . . . | 183,600 | 295 | 191,300 | 292 |
| Bessemer steel . . . | 85,200 | 21 | 84,800 | 19 |
| Open-hearth steel . . | 198,300 | 42 | 225,200 | 46 |

**Belgian Iron and Steel Production.** — The production of pig iron and steel in Belgium has been as follows in the past two years, in metric tons of 2,204.6 pounds:

|  | 1902 | 1904 |
|---|---|---|
| Basic and Bessemer . . . | 709,960 | 867,550 |
| Foundry . . . . . . | 104,540 | 91,860 |
| Forge . . . . . . | 254,710 | 257,090 |
| Total pig iron . . . . | 1,069,210 | 1,216,500 |
| Ingots, blooms, etc. . . . | 776,875 | 981,740 |

**Manganese Ore Production.** — The United States Geological Survey has just issued its report on manganese ores in the United States in 1902. The production was 16,477 long tons, valued at $177,911, showing an increase over 1901 of 4,482 tons in quantity and $61,189 in value. Montana in 1902 produced 9,000 tons or over half the total, although not a producer in 1901. Georgia produced 3,500 tons and Virginia 3,041 tons. Besides the manganese ore production, there is some manganese in many of the iron ores raised, and a small proportion is used in the manufacture of spiegeleisen. In Colorado the larger part of such manganiferous iron ore is utilized as a flux.

In connection with the figures of production in the United States, we may note that a much larger quantity of manganese ore is imported than is produced, the imports having been 146,056 tons in 1903, 235,576 tons in 1902 and 165,722 tons in 1901. Nor is the entire domestic demand for manganese iron supplied even in this way, since imports of the metallic products have been as follows:

| Year ended June 30 | Spiegeleisen | Ferro-manganese |
|---|---|---|
| 1901 | 16,308 | 8,995 |
| 1902 | 31,416 | 37,618 |

**Production of Bessemer Steel Ingots and Rails in 1903.** — The American Iron and Steel Association has completed compiling the returns of Bessemer steel production in the United States last year, and reports the Bessemer ingot production to have been 8,577,228 gross tons of 2,240 pounds, a decrease of 561,135 tons, or six per cent, from 1902. Castings are included with ingots.

The production of Bessemer steel rails was 2,813,583 tons, showing a decline of 62,710 tons from 1902. The tonnage includes 13,248 tons of renewed rails made by companies which make Bessemer ingots. The figures include street rails as well as standard steam rails. To ascertain the total production of rails in the United States there must be added a small tonnage of open-hearth rails and iron rails, which will be returned later. The production of open-hearth rails will of course show a large increase.

The proportion of rails of the heaviest sections has increased very much. In 1903 the percentage of the total Besse-

mer steel production, which was 85 pounds per yard or heavier in section, was 40.4 per cent; in 1897 it was only 20.8 per cent of the similar total. When the completed returns are in it will be possible to make more extensive comparisons.

We present below a table showing the production of Bessemer steel ingots and castings from the earliest year for which statistics were returned, all in gross tons:

| | | |
|---|---|---|
| 1867..... 2,679 | 1879..... 829,439 | 1891.....3,247,417 |
| 1868..... 7,589 | 1880.....1,074,262 | 1892.....4,168,435 |
| 1869..... 10,714 | 1881.....1,374,247 | 1893.....3,215,686 |
| 1870..... 37,500 | 1882.....1,514,687 | 1894.....3,571,313 |
| 1871..... 40,179 | 1883.....1,477,345 | 1895.....4,909,128 |
| 1872.....107,239 | 1884.....1,375,531 | 1896.....3,919,906 |
| 1873.....152,368 | 1885.....1,519,430 | 1897.....5,475,315 |
| 1874.....171,369 | 1886.....2,269,190 | 1898.....6,609,017 |
| 1875.....335,283 | 1887.....2,936,033 | 1899.....7,586,354 |
| 1876.....469,639 | 1888.....2,511,161 | 1900.....6,684,770 |
| 1877.....500,524 | 1889.....2,930,204 | 1901.....8,713,302 |
| 1878.....653,773 | 1890.....3,688,871 | 1902.....9,138,363 |

1903............8,577,228

# RECENT PUBLICATIONS

*Microscopic Analysis of Metals,* by F. Osmond; edited by J.
E. Stead; 178 5 × 7½ in. pages. 91 illustrations. Charles Grif-
fin & Co. London. 1904. Price, $2.50 — This welcome book
consists of an English translation of two important papers by F.
Osmond, namely, " Metallography Considered as a Method of
Assay," read at the Stockholm Congress (August, 1897) of the
International Association for the Testing of Materials, and
" Micrographic Analysis of Carbon Steels," published by the
Société d'Encouragement pour l'Industrie Nationale in 1895 and
in an enlarged and revised form in 1901. From the editor's intro-
duction the reader might infer that these papers are here presented
in the English language for the first time, whereas the first one
was published in a slightly abridged form in Vol. I, No. 1, of *The
Metallographist* (January, 1898), very shortly, therefore, after its
presentation, and a full translation of Osmond's first version of
his second paper was published in December, 1902, in the " Pro-
ceedings of the Engineers' Society of Western Pennsylvania."
Two appendixes are also included, the first one being a short de-
scription of apparatus employed by Osmond in his metallographic
work, while in the second the author conclusively demonstrates
the relative softness of austenite.

Osmond's beautiful photo-micrographs are very satisfactorily
reproduced. It is unnecessary to add that this book will be warmly
received by all students of metallography in English-speaking
countries.

*Introduction to the Study of Metals* (Introduction à l'Etude
des Metaux), by Alfred Ditte, Professor of Chemistry at the
University of Paris; 488 6 × 9 pages; illustrated. Société l'Edi-
tions Scientifiques. Paris. 1902. Price, $4.50. — The author, in
his preface, describes the purpose of this book, which is to treat
of the metals in general, considering only those characteristics
which are common to all and in which are to be found answers

to the first questions which come to mind when we undertake the study of metals. The metals! whence do they come? What are they? Where do they go?

Whence do they come? That is to say how they are found in nature, free or combined, and when in the latter form, how they are extracted and converted into industrial products.

What they are? That is to say what is their nature, what are their essential qualities, their behavior towards other bodies, as well as their natural relations?

Where they go, when, after having been isolated from their ores, they have completed their period of usefulness?

In this age of excessive specializing we lose sight too readily of the close relation existing between many phenomena, especially in the domain of applied science. The metallurgical specialist loses sight too readily of the common philosophical principles upon which all metallurgical arts are based, of the common characteristics and properties of the products, and who will deny that this broader view of the subject is not much to be desired? Not only does it go for culture, but it constitutes an invaluable weapon with which to promote the advancement of the art in any special direction.

Professor Ditte is to be congratulated for having written this excellent book in which this broader view of metallurgy and the physics of metals is presented with so much authority and clearness.

*An Outline of the Metallurgy of Iron and Steel,* by A. Humboldt Sexton, Professor of Metallurgy in the Glasgow and West of Scotland Technical College; 620 5½ × 8½ in. pages. 196 illustrations. The Scientific Publishing Co. Manchester. 1902. Price, $6.40. — In this very good book, which we consider to be much more than an outline of the subject, the author describes the Metallurgy of Iron and Steel in its various phases. and his treatment includes a description of the most recent improvements introduced into the art of iron and steel making as well as of the results of modern research relating to the scientific side of the subject. In writing this book, Professor Sexton's purpose was " to meet a need which he has felt, viz., that for a book which in one volume of moderate type shall cover the whole field of the Metallurgy of Iron and Steel." The book contains a very

satisfactory chapter on the Structure of Iron and Steel, in which most of the photo-micrographs used are from Stead. The Nomenclature of Metallography recommended by a committee appointed by the Iron and Steel Institute is reproduced as an appendix.

*Metalle* (Geschichte, Vorkommen und Gewinnung) — *Metals* (History, Occurrence and Extraction) — by Bernhard Neumann: 421 6½ × 9½ pages. Numerous tables and diagrams. Wilhelm Knapp-Halle. Germany. 1904. — This book contains an exhaustive collection of statistics relating to the production and prices of all metals produced on a commercial scale. The data has apparently been compiled with great care and is typographically presented in a very attractive form.

*Iron Foundry* (Fonderie de Fer), by Jules Boiteux; 83 6¼ × 9¾ in. pages. Many illustrations. Paper cover. Dufrane-Friart. Frameries, Belgium. 1903. Price, $1.50. — This book includes a practical description of the various operations carried on in an iron foundry, as well as of the materials used. The author divides its subject into four chapters, the first dealing chiefly with the classifications of the various brands of European pig iron, the second with the cupola, the third with coke, sand and other materials, while the fourth is devoted to the description of ladles and of the teeming operation. This work is an able and practical description of Belgian, and, in general, European, foundry practice. It should be of value to all interested in foundry operations. The author is manager of the Blast-Furnaces and Foundry of La Louvière, Belgium.

*Amalgams and their Application* (Les Amalgames et leurs Applications), by Léon de Mortillet; 50 6½ × 10 in. pages Paper cover. Bernard Tignol. Paris. — An interesting description of the properties and nature of various amalgams.

# PATENTS

## RELATING TO THE METALLURGY OF IRON AND STEEL

### UNITED STATES

**751,733. FEED TABLE FOR ROLLING-MILLS.** — Sigmund V. Huber, Pittsburg, Pa. A feed table for rolling-mills having in combination means for guiding or directing an article along the table, means for raising and lowering the table, means operative by the table for shifting the guides laterally and means for varying the extent of such lateral movement.*

**751,801. METHOD OF ROLLING METAL PLATES.** — Arthur J. Maskrey, Martins Ferry, Ohio. A method of producing sheets from a bar of metal which consists in first heating the bar and passing it through a short series of reducing-rolls arranged in tandem, returning the partly-reduced product to a reheating-furnace, reheating the product, passing it through said short series of reducing-rolls a second time in a plurality of thicknesses, opening the pack, matching the sheets thereof together again in a plurality of thicknesses, doubling the pack, returning said pack to a reheating-furnace, reheating it, and finishing the sheets in packs by a series of passes through the finishing-rolls.*

**752,054. PROCESS OF TREATING IRON AND STEEL.** — Ewald Engels, Düsseldorf, Germany. The process that consists in treating iron or steel in a solid state with solid carbide and an agent that decomposes such carbide and causing a reaction by means of heat, for substantially the purposes set forth.*

**752,411. MANUFACTURE OF SHEET METAL.** — Alexander Paterson, Wilkinsburg, Pa. A method of making sheet metal, consisting in heating a pack of sheets in a heating-furnace to a rolling temperature, transferring the pack while hot to a second heating-furnace, in which the pack is maintained at a rolling temperature, and removing the same therefrom for rolling.*
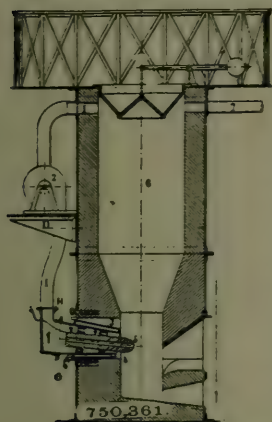
**752,743. ROLLING-MILL.** — Raymond D. York, Portsmouth, Ohio. In a rolling-mill the combination with top and bottom rolls, of means for producing a relative adjustment between the top and bottom rolls, a side roll, means for moving the side roll outwardly and inwardly transversely to the plane of relative adjustment between the top and bottom rolls, a bearing-block for said side roll and means mounted independently of the top and bottom rolls and coöperating directly with said block for raising and lowering the said roll.*

**752,980. MACHINERY FOR THE MANUFACTURE OF METALLIC TUBES, ETC.** — William U. Jackson, Heath Town, and Francis H. Lloyd, Lichfield, England. The combination of two pairs of rolls, and a mandrel operative in connection with each pair of rolls, the said pairs of rolls being arranged end to end and being rotative in opposite directions, each pair of

rolls having a series of gradually-diminishing eyes or grooves, the eyes or grooves of one pair of rolls alternating in size with the eyes or grooves of the other pair, thereby to permit a series or cycle of rolling operations to be conducted by the two pairs of rolls on a tube or billet to be treated thereby, combined with a pair of traveling tables, one at each side of the rolls, the tables being arranged to travel backward and forward simultaneously.*

750,361. ELECTROMETALLURGY OF IRON OR STEEL. — Henri Harmet, St. Etienne, France. A process of continuously and sequentially reducing and fusing iron ores by electrometallurgy, which consists in first charging the ore and an excess of reducing carbon into the upper portion of an electric furnace; second, heating the base of the furnace from electrodes to form a fusion zone or crucible in the furnace; third, conveying gas taken from above the charge into the fusion zone adjacent to the electrodes; fourth, forcing said gas under pressure through the fusion zone to thereby diffuse the heat of the zone, extend its area and convert the gas into carbon monoxide, and finally forcing the carbon monoxide thus formed through the charge to create a reducing zone in the charge above the fusion zone of the furnace.*

753,712. METALLURGICAL FURNACE. — Ferdinand Kepp, Brooklyn, N. Y. A metallurgical furnace including a discharge-flue, a melting-chamber and a superposed initial heading-chamber, the chambers having independent communication with the discharge-flue at their rear ends,
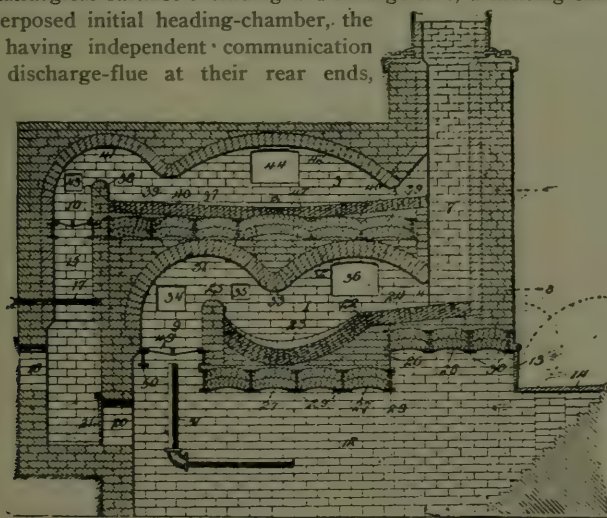
separate heating means arranged to direct products of combustion through the chambers to the flue, and means for establishing communication between the chambers at points intermediate of their ends.*

753,408. ROLLING-MILL. — David H. Lentz, Joliet, Ill. In a rolling-mill, the combination with a pair of rolls between which a rail may be grasped and fed, the rolls being placed in substantial alinement, of a third roll acting upon the rail at right angles to the aforesaid rolls and engaging one side of the rail, an abutment engaging the other side of the rail, the abutment being in the form of a bar, and means whereby the bar may be caused to travel as the rail is passed through the rolls.†

753,603. STEEL-CONCRETE CONSTRUCTION, ETC. — John S. Metcalf, Chicago, Ill., assignor to John S. Metcalf Co., Chicago, Ill., a corporation of Illinois. This construction consists of a stay comprising sections formed with adjacent hook-equipped extremities, a link engaged by the hooks, and means at each link forming a part of the stay for forcing the hooks into close engagement with the link.*

753,875. ELECTRICAL MANUFACTURE OF IRON ALLOYS. — Gustave Gin, Paris, France. A process for electrically producing an alloy of iron with the simultaneous production of oxides of alkalies, consisting of mixing a silicic acid with the sulphate of the alkali, adding carbon to the mixture heating the same in an electric furnace with the production of the silicate
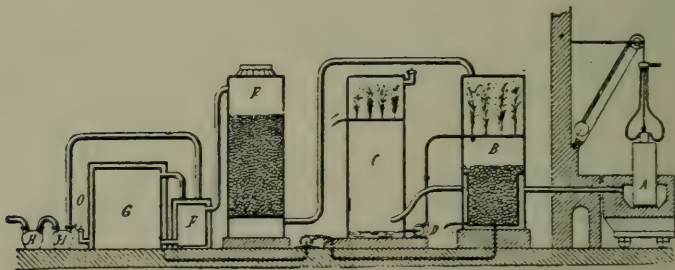


of the alkali; then introducing this alkali silicate into a second furnace, adding an oxide of iron, and carbon thereto, heating the same with the production of ferrosilicon and oxide, of the alkali, and collecting the oxide of the alkali in the form of a sublimate of the same.†

754,154. PROCESS OF MANUFACTURING STEEL. — Otto Massenez, Wiesbaden, Germany. A process of manufacturing steel from chromiferous pig iron in the reverberatory furnace which consists in melting the iron, forming in contact therewith a slag capable of dissolving chromic oxide, and adding a flux capable of counteracting the stiffening action of chromic oxide upon the slag.†

754,162. BLOWING ENGINE. — Edwin Reynolds, Milwaukee, Wis. In combination with a chambered cylinder-head, a valve-seat formed thereon;

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* "Mining and Scientific Press."
† "Engineering and Mining Journal."

a fixed stem extending down toward said seat ; a valve mounted and mov-
able upon said stem toward and from the seat ; a tube mounted within the
stem and bearing upon the inner face of the valve at one end ; a plug
fitting within the upper end of the stem ; and a spring interposed between
the lower closed end of the tube and the lower end of the plug.*

754,301. MANUFACTURE OF HARDENED-STEEL PROJECTILES OR OTHER
ARTICLES. — Robert A. Hadfield, Sheffield, England. A method of harden-
ing nickel-chromium-steel articles, which consists in heat-treating the
article to raise the temperature thereof to about 900° C. and upward, and
thereafter subjecting such heated article to the direct action of a blast or
current of air.*

754,337. BLAST-FURNACE. — John W. Pack, Berkeley, Cal. The com-
bination in a furnace having a shaft and crucible, and
an exterior water-jacket, of an interior hollow water-
jacket the outer walls of which are spaced from the
inner walls of said exterior jacket, said interior jacket
having its upper portion converging and entering the
lower part of the stack whereby said converging portion
supports and arrests the ore passing from the furnace.*
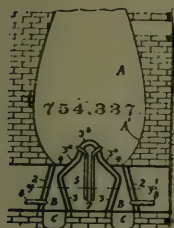
754,910. INGOT CRANE. — Clarence L. Taylor, Alli-
ance, Ohio, assignor to the Morgan Engineering Com-
pany, Alliance, Ohio. In an overhead traveling crane,
the combination with a main drum and means for rotating same, of an
auxiliary drum geared to the main drum so as to be actuated thereby and
means for changing the position of the auxiliary drum with relation to the
main drum.*

## GREAT BRITAIN

4,981 (1903). IMPROVEMENTS IN THE TOUGHENING OF MANGANESE
STEEL. — R. A. Hadfield, Parkhead House, Sheffield. In the specification
dated March 6, 1902, No. 5,604, is described an improved treatment of
manganese steel for the purpose of toughening it, according to which
the steel, after being slowly heated to a temperature of about 750° C. to
800° C., is heated as quickly as possible to a temperature of from
940° C., to 1,125° C. before being plunged or quenched in cold water.
According to the present invention, in order to improve the final toughen-
ing treatment, the manganese steel, after being heated up to the desired
temperature of from 940° C. to 1,125° C., is, before being plunged or
quenched in cold water, allowed to cool down to, say, about 800° C., and
again heated to the proper toughening point, after which the steel is
plunged or quenched in cold water. The supplementary cooling and
reheating operations may in some cases be carried out more than once
before the final quenching in cold water is effected.†

28,178 of 1902. PURIFYING STEEL. — C. Koller, Salgotarjan, Hungary.

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* " Engineering and Mining Journal."
† " The Colliery Guardian."

Separating oxide from molten steel by submitting it to centrifugal action in a separator.*

1,562 of 1903. STEEL MAKING. — J. Baxeres de Alzugaray, London. Making refined steel direct from ores by making the ground ores into briquettes with coke, lime, fluorspar, common salt and slag, and smelting.*

23,746 of 1903. IRON ORE BRIQUETTES. — G. Grondal, Djursholm, Sweden. An improved furnace for burning briquettes of ore so as to make them hard enough for the blast-furnace.*

25,932 of 1903. STEEL MAKING. — E. Engels, Düsseldorf, Germany. Adding carbon to steel in the form of carbide of silicon, mixed with sulphate of soda, which helps decompose the carbide.*

784 of 1903. MAKING VANADIUM ALLOYS. — H. L. Herrenschmidt, Genest, France. Making vanadium alloys by first producing vanadate of soda from ores and then precipitating the vanadium by a soluble salt of the metal with which the vanadium is to be alloyed.*

28,938 of 1902. PURIFYING IRON. — W. S. Simpson, London. Purifying molten iron from carbon and oxide by subjecting the vessel to violent up-and-down concussions, so as to make the lighter constituents of the iron come to the top.*

4,981 of 1903. MAKING MANGANESE STEEL. — R. A. Hadfield, Sheffield. Improvements in toughening manganese steel, by first heating slowly to 750° or 800° C., then rapidly to 940° or 1,125° C., then allowing to cool to 800° C., and again heating to 940° or 1,150° C., after which it is quenched in cold water.*

5,597 of 1903. CASE-HARDENING STEEL. — C. Lamargese, Rome. Use of a mixture of lamp black and charcoal for case hardening steel, the addition of lamp black hastening the process.*

6,283 of 1903. FURNACE. — G. Grondal, Djursholm, Sweden. An improved form of furnace for making iron sponge from fine ores.*

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* " The Colliery Guardian." ·
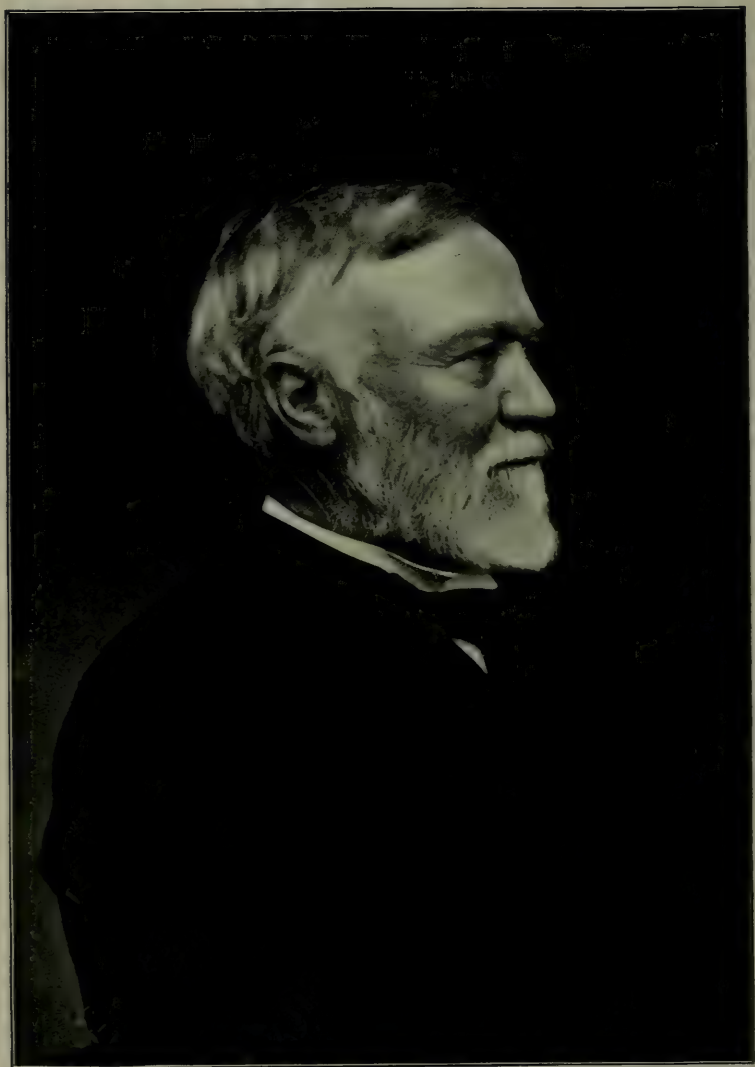
ANDREW CARNEGIE
PRESIDENT OF THE IRON AND STEEL INSTITUTE

## THE IRON AND STEEL INSTITUTE

THE thirty-fifth annual meeting of the Iron and Steel Institute was held May 5th and 6th at the House of the Institution of Civil Engineers, London, the chair being occupied by the President, Mr. Andrew Carnegie, who was supported by a large and fully representative gathering of members.

The report of the Council shows a net increase of 71 members during the year 1903, the total membership being 1,781; it also indicates the healthy condition of the finances of the Institute. For many years past it has been the practice of the Iron and Steel Institute to republish from time to time rare and interesting papers relating to the history and manufacture of iron and steel; and it having been suggested by the West of Scotland Iron and Steel Institute that it would be a useful service to metallurgy to reprint Bunsen and Playfair's report on the gases evolved from iron furnaces, read in 1845, the Council of the Iron and Steel Institute readily consented to co-operate in the work. A copy of the reprint, with an introductory note and portraits, was forwarded to every member.

The retiring Members of Council, whose names were announced at the Düsseldorf meeting, are: Vice-Presidents, Sir J. G. N. Alleyne, Bart.; Mr. G. J. Snelus, F. R. S.; and Mr. James Riley. Members of Council, Mr. William Beardmore, Mr. David Evans, Mr. Victor Cavendish, M. P., Mr. Arthur Cooper and Mr. W. Evans.

Owing to the election of Mr. Carnegie as President, a vacancy arose on the Council which was filled by the election of Sir Benjamin Hingley, Bart., as Vice-President, and of Mr. John M. Gledhill, of Sir W. G. Armstrong, Whitworth & Co., Ltd., Manchester, as member of Council. As no other members were nominated up to one month previous to this meeting in response to the announcement made at the Barrow meeting, the retiring members of Council are presented for re-election.

From " Engineering " of May 6th we quote the following description of the presentation of the Bessemer medal:

" The next business was the presentation of the Bessemer medal, which this year has been awarded to Mr. R. A. Hadfield, whose discoveries in metallurgy secured for him a position of scientific eminence, whilst still quite a young man, and who, as years have gone, has continued to add to our steadily growing knowledge of the properties of metals and alloys. His scientific papers, inaugurated by an account of his epoch-marking discoveries in manganese steel, communicated to the Institution of Civil Engineers in 1888, already are twenty in number, and will undoubtedly be greatly increased, both in quantity and value, before the termination of his career. It is given to but very few to obtain eminence both in research and in the conduct of business, but the remarkable success of the steel foundry at Sheffield of which Mr. Hadfield has been managing director since 1888, having been appointed to this most responsible position at the early age of 29, is a striking testimony to his possessing the qualities needed for success in both careers. The years which have since elapsed have been the period during which not only the bulk of Mr. Hadfield's scientific work has been done, but have been marked by an enormous development of his business responsibilities. The works now cover an area of over 90 acres, and include the largest foundry in the world. Size is, however, the least remarkable feature of this foundry, for here, though more especially in the war-material department; castings are produced giving results hitherto attainable only with the best forged steels. It would be impossible to adduce more striking testimony of the value of scientific knowledge in foundry practice. Mr. Carnegie, in presenting the medal, remarked that it had had many distinguished recipients before, but it had never been presented with a greater unanimity of opinion as to the great

value of the work done by the new medallist, whose achievements it would be superfluous in him to record. Mr. Hadfield was at the top of his profession, and must regret that there were no other heights for him to attain. His establishment at Sheffield was unique in its special line, but he would find that a man who was master of his work was eventually mastered by that work."

"In reply, Mr. Hadfield referred to the difficulty he had in adequately expressing his thanks and appreciation for the high honor conferred on him by the Council, an honor which he considered was not bestowed merely on himself, but also on the town from which he sprang, and which was still the leading center of the world for the highest quality of material and the wide range of special products. He thought, however, it was a pity that instead of gold the medal was not made of steel, particularly if some of Bessemer's first product could have been obtained with which to make the medals. He felt it peculiarly gratifying that he received the medal from the hands of Mr. Carnegie, from whom he had years ago received much kindly encouragement and assistance, and he expressed to him, as representing America, the hope that the greatest possible success would attend the St. Louis Exhibition. As to his own acheivements, which the Institute had seen fit thus to recognize, he would only claim the merit of persistent hard work. The labor involved in metallurgical research was very great. At the time of the discovery of manganese steel the systematic study of the iron alloys was almost virgin ground, and he wished to acknowledge the assistance and coöperation he had received from numerous friends, such as, to mention a few names only, M. Osmond, Professor Barrett, Dr. Sorby, Dr. Fleming, Professor Kennedy, Professor Arnold, Mr. Stead, the late Mr. J. F. Barnaby, Professor Ledebur, and Mr. H. M. Howe. He had also to acknowledge his great indebtedness to his own staff, some of them, alas, no longer here. As of some historic interest he placed on the table specimens of the first manganese iron alloy made by him twenty-two years ago — in September, 1882 — which he offered to the Institute. The specimens represented the three critical points in manganese-iron products — viz., the brittle percentage containing about 5 per cent manganese; the very tough product with 11 per cent manganese; and the harder one with 17 per cent of manganese."

The report of the scrutineers announced that all the candi-

dates had been elected, the number (148) being larger than had ever before been elected at one time. No doubt the prospect of the American visit has had a stimulating effect on the desire to join the Institute.

The secretary next announced that the following awards had been made from the Carnegie Research Fund: Scholarships of £100 to Messrs. J. D. Brunton, H. C. H. Carpenter, E. G. L. Roberts and E. A. Wraight (jointly), F. Rogers, and W. Rosenhain. A further grant of £50 was also made to Dr. O. Boudouard, of Paris, in continuance of former researches. The Carnegie medal was awarded to M. P. Breuil, of Paris, in the following words:

The President: "With regard to the Carnegie medal I should like to read a letter which has touched the Council as I believe it will touch you. This is a letter from the winner of the Carnegie medal, a Frenchman of Paris, M. Breuil. It is addressed to Mr. Brough, our secretary:

"'DEAR SIR: I scarcely know how to give expression to the extreme gratification afforded to me by your kind letter, and words fail me with which to convey the sense of my deep gratitude to your President and Council for their recompense of my labors. This acknowledgment of my work has indeed caused me the most profound pleasure. I may, however, perhaps tell you, honored sir, that what really affords me the chief pleasure of all is, not that I have had the honor of being selected for the award of the great favor you have been pleased to bestow upon me, nor even that I see enhanced the name of my laboratory; it is the thought of the profound joy which will be experienced by my parents, two good French peasants, now advanced in years, poor and infirm, and living in a remote country village, on learning that their son has achieved so high a mark of distinction. (Cheers.) For your constant kindness to me, gentlemen, my thanks will ever be due, as well as for the honor conferred upon me, of which I scarcely feel that I am the worthy recipient, and I will use every effort to avail myself of your suggestion to come and receive at your hands the beautiful medal. — Yours faithfully, P. BREUIL.'

"Gentlemen, it is to that man that I am now, as your agent, to deliver the gold medal. If I had written volumes upon his character .I could not have revealed the man more to you than in these few words of his letter." (Cheers.)

On M. Breuil presenting himself the President addressed him as follows:

" M. Breuil, I have many times regretted that in my youth I did not learn your beautiful language that I might address you in it on this occasion. But there is a language of the heart in which I can speak to you, and of the head, and that is a common and universal language; and I now speak to you in my native tongue only because I do not know yours sufficiently well to express myself freely in it. France has, from the earliest days, been the favorite friend of one branch of the English-speaking races. Recently France and Britain have become friends. (Cheers.) And I believe they are to continue growing in friendship. I think we will never know anything but a generous rivalry in the domain of peace and the acquisition of knowledge. I have just returned from Paris, and I met some of the men for whom France is famous. Pasteur has passed away. I have been with Berthelot, your great scientist of world-wide fame. I have been with M. Curie and his wife, the discoverers of radium. What a class of men — disdaining wealth, refusing patents for anything they have done, declining rank when it was in their power to attain it. They have led simple lives, dedicating themselves to the service of their fellow-men. Living in poverty they have realized Franklin's rule of life: ' The highest worship of God is service to man.'

" I think your country, France, stands in the front rank with such individuals. But, sir, we are not without them in the English-speaking races. I could mention many names. I will take the great liberty of mentioning one — Professor Bauerman. I believe he is a fit colleague to Sir Lowthian, to Pasteur, Berthelot, and Curie, and such men who labor not for what we meaner men consider the crown of victory, but for that higher crown which disdains the adornments of society and rank and wealth, and who live pure, simple lives, having for their end not self-gratification, but the well-being of their fellow-men. I see in you sir, such a Frenchman. You have begun your career. The little touch in your letter — you look not to the world for applause; you look not even to your own gratification, but in the hour of your triumph and your victory: ' My father and my mother — my parents ' — that their son has been able to give them happiness — that is the prize, and that is a prize indeed. (Cheers.)

I hope and expect that you will be one of that noble band, Pasteur, Berthelot and Curie."

An extra medal was then presented to Mr. Percy Longmuir, after which the following papers were read and discussed: "Explosion Produced by Ferro-Silicon," by Mr. A. Dupré and Captain M. B. Lloyd. "The Manufacture of Pig-Iron from Briquettes at Herräng," by Professor Henry Louis. "Notes on the Production and Thermal Treatment of Steel in Large Masses," by Mr. Cosmo Johns.

In the afternoon an exhibition was held of pyrometers suitable for metallurgical work.

The proceedings were resumed on Friday, May 7th, with the President in the chair. The Secretary read an abstract of the paper on "Pyrometers Suitable for Metallurgical Work," prepared by a committee consisting of Messrs. Stead, Hadfield and Brough. This subject was discussed at length by Messrs. Stead, Le Chatelier, McWilliam, Campion, Louis, Turner, Gledhill, Thwaite, James, Hanson, Bell, Rosenhain, Arnold and Hadfield.

The following papers were then read and discussed:

"On the Manufacture of Coke in the Hüssener Oven." By C. Lowthian Bell.

"On the Range of Solidification and the Critical Ranges of Iron Carbon Alloys." By H. C. H. Carpenter and B. F. E. Keeling.

"On Troostite." By H. C. Boynton (Harvard University).

"On the Synthesis of Bessemer Steel." By F. J. R. Carulla.

"On the Thermal Efficiency of the Blast-Furnace." By W. J. Foster.

"On the Plastic Yielding of Iron and Steel." By Walter Rosenhain.

"On the Use of Steel in American Lofty Building Construction." By B. H. Thwaite.

"On Tests of Plain Bars and Notched Bars." By P. Breuil (Paris), Carnegie Research Scholar.

"On the Influence of Varying Casting Temperature on Iron and Steel." By P. Longmuir, Carnegie Research Scholar.

At the dinner of the Institute the guests included the Duke of Argyll, Earl Gray, Lord Chief Justice Alverstone, Lord Kelvin, Lord Hugh Cecil and Seth Low, formerly mayor of New York. Mr. Carnegie in his address said it was largely because the occupant of the British throne knew other lands so well and made

friends everywhere that great beneficent changes occurring in the mutual relations of these lands were seen. He hoped that nothing would ever disturb the satisfactory relationship of the motherland with the United States. The next meeting of the Institute will be held in New York City in October, preceding a trip to various steel-making centers and later to St. Louis, by 500 visiting members of the Institute.

Of the thirteen papers presented at this meeting of the Iron and Steel Institute seven are reproduced in full in the present numbr of *The Iron and Steel Magazine.* The balance of the papers will be published in our July issue.

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## THE THERMAL EFFICIENCY OF THE BLAST-FURNACE*

By W. J. FOSTER
Darlaston, England

M UCH has recently been published by different authorities on blast-furnace practice, describing the great difference between the English practice as compared with that of America



from an economical point of view, and the difference is considered to be due to the enormous outputs of the American furnaces as compared with the small outputs of the furnaces in this country. Although the subject has been in this way thoroughly explained, yet it seems to me that there is a great field open for research from a combined practical and theoretical point of view, and I think the time has now arrived when this question, especially in Great Britain, should have serious consideration.

Although the subject of the thermal efficiency of the blast-furnace was a question that drew the attention of the Iron and

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* The Iron and Steel Institute, May (1904) Meeting.

Steel Institute to one of the first papers which was read before this Institute by Sir Lowthian Bell, it appears to me that the question has not had the amount of attention from any other author that it really deserves, especially during the last few years.

The particular furnace that I have under examination, although not equipped with modern machinery and blast-heating apparatus, etc., may be interesting from the fact that the materials used were chiefly silicates of iron, in the form of flue and tap cinders, together with a small quantity of ferric oxide; it is the furnace at present blowing at Darlaston, having a height of 72 feet 6 inches, and a capacity of 16,000 cubic feet.

Since Neilson's time many attempts have been made to describe technically the theory of hot-blast as applied to the blast-furnace. Among the most important authorities are Professor W. A. Miller of King's College, London, Professor Clark of Aberdeen University, Dr. Percy, and Sir Lowthian Bell. The three former investigators attribute the theory to the deficiency of heat in the hearth, which left us very little more in advance than Neilson's explanation, while Sir Lowthian Bell considers the heat actually taken into the furnace by the blast, which is measured in the form of calories by simply multiplying the weight of the blast by its specific heat and its temperature, which he considered would account for the reduction of fuel. He also remarks that, by increasing the capacity of a cold-blast furnace, we should have something like the same effect as regards the fuel consumption as that realized by the introduction of hot-blast at the tuyères, but from my own experience I do not find this to be the case in Staffordshire when smelting mill cinders, etc., which is the custom in this particular district. Nevertheless, this train of reasoning would be absolutely correct in an ideal blast-furnace, where the quantity, composition, and temperature of the escaping gases per unit of iron made would be the same with the application of either hot or cold blast respectively. It must be understood also that, to make the above law correct in an ideal furnace, which of course we do not possess at present, we must take into consideration the increased heat absorbed by the hot blast at high temperatures, which is due to the partial dissociation of the water molecule before entering the furnace, which has a constant value, being proportional to the temperature and pressure; and is governed by the fact that, at a white

heat, water vapor is completely decomposed without the intermediate action of any other body; consequently, the whole of the heat due to decomposition is not to be accounted for in the hearth of the furnace. For example, at Darlaston I found that 6.376 units of air are required per unit of pig, when using cinder as mentioned above, and the fuel consumption at the time of examination was 1.46 tons, which may be represented by the simple formula, $6.376 \times 454.4° \text{ C.} \times 0.24 = 695.34$ calories; the quantity of water vapor entering the furnace per unit of pig was found to be $0.00624 \times 9 = 0.05616$, so that the heat formation should be $0.00624 \times 34,462 = 215$ calories.

It will be seen that the 215 calories, minus the latent heat of the water existing in the blast, may be represented thus:

$$(0.00624 \times 34,462) - (0.00624 \times 9 \times 537) = 184.842;$$

so that 184.842 calories would be absorbed at the expense of the fuel in the hearth; but in the case under examination, where the air is allowed to pass into the furnace at 454.4° C., the heat absorbed in the hearth would still be less than shown above, and may be represented by the following formula to be $(0.00624 \times 34,462) - [(0.00624 \times 9 \times 537) + (0.00624 \times 9 \times 454.6 \times 0.4805)] = 172.58$ calories, so that the actual heat taken into the furnace with the hot blast would be

$$(695.34) + (215 - 172.58) = 737.76 \text{ units.}$$

Now, applying this method to the furnace at Darlaston under the conditions given, I find that the calories injected into the furnace with the blast equal 2.075 cwts. of coke per ton of pig. As a matter of fact, I find that, under the conditions mentioned, a lowering of the temperature of 200° C. alone would more than account for this quantity; consequently we must look for another theory to explain the hot-blast problem, for under these conditions it is quite evident that the theoretical limit for the advantage of heating the air with such materials as flue cinders, etc., would only occur when the quantity of carbon in the hearth is not sufficient to combine with the oxygen of the ore and metalloids which would be reduced in the hearth and lower part of the bosh. It is quite certain that to decompose and reduce the silicates and phosphates of iron, etc., in the neighborhood of the hearth and tuyères with a minimum supply of air-blast per unit of iron, would certainly lead to great economy of fuel; but

to reduce these bodies, which are endothermic at 0° C., would require a very high temperature to convert them into exothermic bodies, which must necessarily be the case in the hearth, if we are to utilize the oxygen from these bodies with advantage to oxydize the carbon when approaching the hearth of the furnace with proportionally less atmospheric air per unit of carbon burnt.

It is quite evident that to ascertain the true nature of the hot-blast theory by means of a mathematical problem would require a thorough knowledge of the physical and thermo-chemical conditions of all the matter involved in the process. This opens out a large field for research, which will not only solve the hot-blast problem, but also the true nature of the whole system.

The following table gives the necessary information of the heat evolved by 1.46 tons of coke, and appropriation of heat to the different branches of the process, calculated from an average approximate knowledge of the weight and analysis of all the matter involved throughout the system. The mode of calculation, which I insert in the appendix, was found to be very nearly the truth, as far as the analysis of the gases from the furnace was concerned. Column I represents the calories for combustion in the coke. Column II represents cwts. of coke for the different parts of the system, and Column III shows the actual cost of the different parts in shillings when the total cost of fuel per ton of pig equaled 23.36 shillings:

| | I | II | III |
|---|---|---|---|
| Reduction of iron oxide . . . . . . . . | 1,391.000 | 3.912 | 3.130 |
| Reduction of silica . . . . . . . . . . | 254.470 | 0.716 | 0.573 |
| Reduction of phosphorus . . . . . . . | 85.630 | 0.241 | 0.193 |
| Reduction of oxides of sulphur . . . . | 0.660 | 0.002 | 0.002 |
| Reduction of oxides of manganese . . . . | 18.090 | 0.051 | 0.041 |
| Reduction of calcium in slag existing as sulphide | 38.437 | 0.108 | 0.078 |
| Expulsion of $CO_2$ from flux stone . . . . | 236.910 | 0.665 | 0.534 |
| Heat carried off by gases, including water in coke | 769.446 | 2.164 | 1.732 |
| Fusion of pig iron . . . . . . . . . . | 330.000 | 0.928 | 0.743 |
| Decomposition of water vapor in blast . . | 172.580 | 0.478 | 0.390 |
| Fusion of slag . . . . . . . . . . . | 548.310 | 1.542 | 1.235 |
| Heat carried off by tuyère water . . . . | 50.992 | 0.144 | 0.117 |
| Heat carried off by cooler water . . . . . | 31.871 | 0.089 | 0.072 |
| Carbon taken up by pig iron . . . . . . | 282.800 | 0.796 | 0.637 |
| Loss due to radiation and absorbed in foundations | 727.164 | 2.052 | 1.635 |
| Combustible matter in gases . . . . . . | 5,444.440 | 15.312 | 12.248 |
| Total heat, coke, and cost from 1.285 carbon in the coke . . . . | 10,382.800 | 29.200 | 23.360 |

The first item in Column I represents the amount of calories required to remove the oxygen from 0.9068 unit of iron introduced into the furnace for the reduction of one unit of pig iron, and in a similar manner for the quantity of silicon, phosphorus, sulphur, and manganese, taken up per unit of pig. It will readily be seen that the heat value for iron oxide is lower than has hitherto been assumed; the usual value being taken from 1780 in furnaces using ferric oxides, but in this particular case the value is reduced, owing to having less oxygen in the material, and to making due allowance for the returned scrap which is added to the charge. The average quantity of oxygen added to the charge was estimated by analysis in the usual way. There is a very important point which I think is worthy of consideration from a thermo-chemical point of view in connection with the heat formation of the various oxides of iron, etc.; for example, it is usual to ascertain the thermal value from magnetic oxide ($Fe_3O_4$), which, by Andrews' calculations, is represented by 265.8 kilogramme units for 168 parts of iron and 64 parts of oxygen. The ferrous and ferric oxide values are quantities given in proportion to the oxygen actually taking part in the reaction, but to my mind the value of the different oxides of iron should be in proportion to the total atoms actually involved in the chemical change, assuming that the physical conditions of the matter undergoing the various chemical changes are the same; for example, 232 units of matter, or seven atoms in magnetic oxide ($Fe_3O_4$), produce 265.8 large units of heat, consequently ferrous oxide (FeO) contains 72 parts by weight of iron and oxygen with two atoms, therefore the heat value should be 7 : 265.8 :: 2 : 75.94, instead of 66.4, as shown by the law represented above, which is estimated from the quantity of oxygen alone, and similarly ferric oxide ($Fe_2O_3$) containing five atoms should be represented as follows by 7 : 265.8 :: 5 : 189.86 units instead of 199.4. Of course, as previously mentioned, these figures are not absolutely true owing to the fact that the solid iron would be oxidized by gaseous oxygen; consequently, to arrive at the true values, we should have to get an exact knowledge of the difference in the specific heat of solid oxygen and gaseous oxygen.

It will be seen that the heat absorbed by the quantity of slag necessary to produce one unit of pig is represented by the value 548.31 calories, the quantity of slag per unit being 1.119

units, so that the actual value attributed to one unit of slag is 490 calories, which is an average of twenty experiments taken from the molten slag at the nearest point to the slag notch in an apparatus which I constructed specially for the purpose; the highest value, 514.5, was obtained when the furnace was working very hot, and the cinder being very gray and limey; on the other hand, the lowest value, 451, was obtained when making forge pig with a dark cinder.

The following is an average analysis of the cinder experimented upon:

| | |
|---|---|
| $SiO_2$ . . . . . . . . . . | 34.950 |
| CaO . . . . . . . . . . | 27.865 |
| MgO . . . . . . . . . . | 15.909 |
| MnO . . . . . . . . . . | 1.176 |
| CaS . . . . . . . . . . | 6.031 |
| FeO . . . . . . . . . . | 0.810 |
| $Al_2O_3$ . . . . . . . . . . | 11.365 |
| $Na_2O$ and $K_2O$, etc. . . . . . . | 1.894 |
| | 100.000 |

The loss due to the heat carried off by the tuyères and coolers was estimated by the exact quantity of water passing through them, multiplied by the temperature and the specific heat, by an average of a great number of experiments. At the foot of each column is given the total quantity of calories, also cwts. of coke and cost in shillings per ton of pig iron. In Column I it will be seen that the heat units, developed by the combustion of 1.285 units of carbon when using 1.46 units of coke, give a total of 10382.8 calories, so that to get a constant value for each particular part of the process we have only to adopt the following formula, thus: in the case of the reduction of iron oxide, we require 3.912 cwts. of coke containing 88 per cent of fixed carbon $= \frac{1391 \times 29.2}{10382.8} = 3.912$, and in a similar manner to get the actual cost of each part of the process. In Column II it will be seen that out of 29.2 cwts. of coke we actually lost $15.312 + 2.164 = 17.476$ cwts. of coke actually carried of by the combustible matter and sensible heat in the gases as they leave the throat of the furnace, leaving for the remainder of the process 11.724 cwts. of coke plus the heat brought in by the hot blast, which gives a total of $11.724 + 2.075 = 13.799$ cwts.

of coke, required for internal purposes under the working con-
dition previously mentioned.   A careful examination of the
figures given in the previous table will give an idea in what
particular part of the system we can expect to realize a saving as
far as fuel consumption is concerned.   In the first place, it will
be seen that the reduction of the oxide of the iron per unit of
pig, and the reduction of silicon, phosphorus, sulphur, manganese,
and carbon taken up by the iron, also the fusion of the pig
iron itself, requires a constant quantity of carbon in the form
of coke, etc., which corresponds in the second column to 6.646
cwts. of coke, so that no matter what conditions of working,
whether in charcoal or coke furnaces, we must attribute a definite
weight of fuel to these parts of the system (assuming that the
iron produced has the same composition) ; therefore we cannot
expect to look for economy in this respect under any conditions
whatever.   On the other hand, all the other figures representing
the remaining parts of the process are subject to alteration ac-
cording to the mode of manufacture ; take for example the
difference in the speed of working the furnace by the application
of brute force, it will readily be seen that we get a direct saving
of fuel which would otherwise be lost by the radiation of heat
from the furnace, and the cooling of the tuyères and coolers,
which saving is practically in proportion to the rate of driving,
assuming that we are dealing with furnaces of the same external
area and thickness of linings ; or, in other words, the material in
the furnace is insulated to the same degree from the atmosphere,
and at the same time having the same quantity of tuyères and
coolers of a given area.   In this particular case we have a furnace
only making 78.23 tons per day, and the amount of coke actually
wasted by radiation, etc., per ton of pig is 2.285 cwts. ; by in-
creasing the speed of working, say up to 469.38 tons per day,
or six times the speed of the furnace under examination, we
shall have a saving of 1.817 cwts. of coke, and the total loss
in this respect would only be 0.368 cwts. instead of 2.285 cwts.
The most particular points in the form of loss that require our
special attention from a thermo-chemical standpoint are the
following, namely, the loss due to the combustible matter in the
escaping gases, which, in this particular case, evolves with the
gases when leaving the furnace 15.312 cwts. of coke, which is
equal to 12.248 shillings per ton of pig ; this item alone is more

than one-half the heat appropriated to the system. Then comes the fusion of the slag, representing 1.542 cwts. of coke, and the sensible heat carried off by the gases, which accounts for 2.164 cwts., also the expulsion of carbonic acid gas from the flux stone, and calcium as sulphide in the slag, together with the decomposition of the water vapor in the blast, all of which represents a total of 19.84 cwts. of coke which cannot be directly accounted for as in the case of the previous examples, and it is quite evident that the various chemical and physical changes that govern the fuel consumption in the items just given, require a great deal of investigation before these very complicated problems are thoroughly solved; nevertheless, it can be shown to a certain extent how every one of the items, by rapid driving and an increase in the blast temperature, would effect a great saving; for example, one would naturally ask how we could expect to get a reduction in the temperature of the escaping gases by increasing the temperature of the blast, and consequently the temperature of the hearth, especially in the immediate neighborhood of the tuyères. As already explained, by increasing the temperature of the hearth, less blast per unit of iron made is required, for the reason that the oxides that are endothermic under ordinary conditions are converted into exothermic bodies, which is in part due to the heat absorbed by the materials on their descent to the hearth, with the result that a great amount of carbon is gasified in the hearth and bosh from the oxygen from these bodies, and therefore less nitrogen per unit, of oxygen would be present in the furnace gases, and also a less quantity of water vapor would have to be decomposed at the tuyères. By this it will also be seen that less gas per unit of material entering the furnace will be required, which simply means a larger quantity of cold materials entering the mouth, with a corresponding reduction of gases; this of course will readily explain the reason for a reduction in the temperature of the escaping gases; this alone will have a considerable influence on the 2.164 cwts. of coke shown by the table in Column II. Then comes the question of a reduction of the temperature in the gases due to rapid driving. This can be explained in a similar manner to the hot-blast question, only in this case we can account for the extra heat accumulated in the hearth as due to less heat per unit of iron being lost by radiation;

or, in other words, extra heat is absorbed by the descending materials that would otherwise be lost by slow driving with an increased loss by radiation, etc., which will hereafter be more particularly described when dealing with the reducing zone of the ordinary furnace. Now comes that very important question of combustible matter in the gases which is shown in the table to represent 15.312 cwts. of coke. This particular question opens out a very large field for future research in thermo-chemistry, which will obviously, when thoroughly understood, lead to great economy in fuel consumption in blast-furnace practice; nevertheless, from a practical point of view, I feel convinced that rapid driving increases the quantity of carbonic acid gas in the gases when leaving the furnace, which points to the fact that a rapid transfer from the reducing zone to the hearth, of the reduced iron and other materials, would result in economy in this direction, on condition that the carbon and fluxes, etc., are heated sufficiently before approaching the hearth. Although in this case we are using a certain amount of forge or mill cinder, which is not reduced in that particular zone where ferric and to a less extent magnetic oxides are reduced, we have previously seen that hot-blast and rapid driving have an influence on the temperature of the escaping gases, etc., so that under these circumstances the reducing and carbon precipitation zone are placed under more favorable conditions, inasmuch as both reactions are exothermic, thus:

$$Fe_2O_3 + 3CO = Fe_2 + 3CO_2.$$
$$(189.86 + 29 \times 3). \quad (96.96 \times 3) = + 14.02.$$
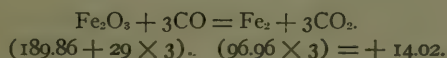
We have a plus value of 14.02 for the reduction of ferric oxide by carbonic oxide, and for the precipitation of carbon by the reaction of metallic iron on carbon monoxide we get an exothermic value of 46.94, thus:

$$Fe + CO = FeO + C.$$
$$29. \quad 75.94 = + 46.94.$$
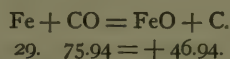
And therefore we require no external heat to produce these chemical changes after chemical action has once started. It is quite probable that a great portion of the precipitate carbon, in the case of slow driving, would, on account of being in a nascent condition when just released from the monoxide, readily combine with the carbonic acid gas with which it would come

in contact to form carbon monoxide. This reaction, which has an endothermic value of 38.96, thus:

$$CO_2 + C = 2CO.$$
$$96.96. \quad 29 \times 2 = -38.96,$$
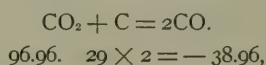
would continue until a great amount of the excess of heat evolved by the previous reaction had been absorbed, or, in other words, a state of thermo-chemical equilibrium had been established, which would naturally be governed by the temperature, pressure, and general conditions of the mass of the materials in this particular zone. It will clearly be seen that once we can account for a saving of fuel in one particular case, there will be established a foundation that will lead to economy in every other part of the system, other than those cases previously mentioned. From time to time many authors have attempted to explain theoretically the reason why a charcoal furnace has more carbonic acid gas in the gases, and at the same time a reduction of temperature as compared with the ordinary coke furnace, but up to the present they have not arrived at a satisfactory solution, chiefly owing to the fact that charcoal is more readily attacked by carbonic acid than coke would be. In the blast-furnace we are confronted with that very important question known to thermal chemists as the influence of mass, and this is the question to my mind that will greatly assist us to decide the great difference between charcoal and coke furnaces. At a first glance it might be suggested, owing to the excessive volume occupied in the charcoal furnace by the fuel, that this would increase the possibility of dissolving the carbonic acid into carbon-monoxide, but of course we must take into consideration the properties of other materials; for example, we must consider the two very important reactions that take place in the reducing zone, namely, the reduction of iron oxides, and the splitting up of carbon monoxide by metallic iron as previously mentioned; both reactions, which are highly exothermic, develop a great amount of heat during the chemical changes. In the charcoal furnace it will be seen that the quantity of oxides of iron present in proportion to the gases is very small as compared with that of the coke furnace, owing to the excessive volume occupied by the charcoal, consequently less heat is evolved in a given quantity of matter, so that we have a less

chance of bringing the temperature of the reducing zone to that point which would decompose the carbonic acid gas generated, owing to the fact that the decomposition of $CO_2$ on solid carbon or metallic iron is accompanied by absorption of heat, which indicates that any of these changes could only take place with the introduction of excess of external heat to the system; and again, it will be realized, the importance of the rapid transference of the reduced iron to the melting zone, consequently that equilibrium of chemical affinity which is established in an ordinary coke furnace is quite different to that in the charcoal furnace. There is another very important point that I wish to mention in favor of charcoal for keeping the temperature down when working under ordinary conditions; as a matter of fact charcoal has a higher specific heat than any other form of carbon used for furnace practice. Some of the different modifications of carbon compared with charcoal may approximately be represented as follows:

| | Specific Heat Estimated by Newth at 45° C. | | Specific Heat Estimated by Author at 100° C. |
|---|---|---|---|
| Diamond . . . . . . | 0.147 | Durham Coppée coke . | 0.231 |
| Graphite . . . . . . | 0.200 | N. Stafford beehive coke | 0.246 |
| Charcoal . . . . . . | 0.241 | Charcoal . . . . . . | 0.275 |

By this it will be seen that charcoal absorbs an amount of extra heat from the reducing zone greater than would be the case with any form of carbon, which would again return to the hearth or bosh where it is required to deal with the residual oxides of iron and metalloids. There is also another very remarkable property of charcoal which is due to the possibility of various varieties, whereby it exposes a very large surface for the absorption of various gases, such as those gases that are the most readily liquefiable, for instance, ammonia gas; there is no doubt that the expulsion of this gas would absorb a large amount of heat in the lower part of the reducing zone, which is partially due to its decomposition into nitrogen and hydrogen. It may be, that owing to the comparatively low temperature in the reducing zone of the charcoal furnace, a portion of the nascent hydrogen given off from the fuel would to a certain extent prevent the action of carbonic acid gas on the carbon, and at the same time act as a reducing agent on the oxides of

iron; on the other hand, any hydrogen that has been liberated from the moisture taken in by the blast, would not act as a reducing agent, as previously suggested by Sir Lowthian Bell, it may be mentioned that the heat formation of hydrogen on the oxides of iron is endothermic. It is quite evident from what has just been mentioned that the ratio of carbonic acid gas to carbonic oxide in the escaping gases is entirely dependent upon the combined physical and chemical properties of the materials undergoing chemical change.

Although I have endeavored to explain the reason of excess of carbon dioxide in the gases from a charcoal furnace, more than what might be expected from a coke furnace, I do not wish it to be understood that the charcoal furnace is the ideal furnace, as far as the ratio of carbon dioxide to carbon monoxide is concerned, for it is quite certain, that if we would reduce oxides of iron without being mixed with carbon, we should have better results as far as the ratio of the gases is concerned, and to prove this for my own satisfaction I conducted several experiments with purple ore in a small cupola. In these experiments I first of all introduced 1 cwt. of coke into the bottom of the cupola, which was allowed slowly to come to a red heat; then I suddenly added to this, 10 cwts. of dry purple ore, and then applied a steady blast which was heated to about 500° C., when I arrived at the following results:

| Time of Experiment | CO Per Cent by Volume | CO₂ Per Cent by Volume | Temperature of Gases | Ratio $\dfrac{CO_2}{CO}$ |
|---|---|---|---|---|
| 6.37 P.M. | not taken | not taken | 135° C | |
| 7.15 " | 12 | 19 | 271° C | 1.58 |
| 7.40 " | 16 | 22.6 | 339° C | 1.41 |
| 8.00 " | 10.7 | 19.4 | 582° C | 1.81 |
| | addition | of fresh ore. | 221° C | |
| 8.40 " | 7.6 | 35.2 | | 4.63 |
| 9.00 " | 8 | 70 | 360° C | 8.75 |
| 9.15 " | 6.2 | 22 | 482° C | 3.549 |

The best results as far as $\dfrac{CO_2}{CO}$ is concerned was at a temperature of 360° C., which occurred twenty minutes after an addition of fresh ore was added. In my concluding remarks I have not thought it necessary at present to go thoroughly into detail with these experiments, but it is my intention still to prosecute further research on the thermal efficiency of the blast-furnace.

## APPENDIX

The average air blown into the furnace per day, after allowing for stoppages and leaks, etc., was found to be 14,491,380 cubic feet; the loss due to clearance, etc., in blowing cylinder and leakage to the furnace, was found to be 36.844 per cent.

Oxygen required to oxydize one unit of carbon to CO at the tuyères

$$= 12 : 16 :: 1 : 1.33$$

Composition of the atmosphere by weight, estimated at 0° C. and 760 mm.

$$
\begin{aligned}
&= \text{Nitrogen} &&.\ .\ .\ . &&76.02 \text{ per cent} \\
&= \text{Oxygen} &&.\ .\ .\ .\ . &&23.07 &&\text{“} \\
&= \text{Hydrogen} &&.\ .\ .\ . &&0.098 &&\text{“} \\
&= \text{Carbon} &&.\ .\ .\ . &&0.0014 &&\text{“}
\end{aligned}
$$

Air per unit of carbon burnt at the tuyères at 0° C. and 760 mm. and 15° C. and 760 mm. respectively

$$= 23.87 : 100 :: 1.33 : 5.571 \text{ taken in grammes.}$$

$$\therefore \frac{36.87 \times 273}{273 + 15} = 34.049 \text{ grammes.}$$

Carbon oxidized by one cubic foot of air at 15° C. to CO

$$= \frac{34.949}{5.571} = 6.272 \text{ grammes.}$$

Weight in kilograms of carbon oxidized at tuyères per day

$$= \frac{14,491,380 \times 6.272}{1000} = 90,889.9.$$

Tons of carbon oxidized per day

$$= \frac{90,889.9 \times 2.2}{2240} = 89.3 \text{ tons.}$$

Air blown into the furnace per day

$$= \frac{89.3 \times 16 \times 100}{12 \times 23.87} = 498.8.$$

Quantity of each element blown into furnace per day estimated in tons

$$100 : 23.8731 :: 498.8 : 119.0792 \text{ of oxygen.}$$
$$100 : 76.0275 :: 498.8 : 379.22517 \text{ of nitrogen.}$$
$$100 : 0.098 :: 498.8 : 0.48882 \text{ of hydrogen.}$$
$$100 : \underline{0.0014} :: 498.8 : \underline{0.00698} \text{ of carbon.}$$
$$\phantom{100 : }100.0000 \qquad 498.79947$$

Carbon available for oxidation, after allowing for that taken up by the pig iron, etc.

Average make of iron 78.23 tons, coke per day $= 114.24$, tons coke per ton of iron, 1.46 tons.

Average analysis of coke:

$$
\begin{aligned}
\text{Fixed carbon} &= 88 \\
\text{Sulphur} &= 1 \\
\text{Ash} &= 10 \\
\text{Moisture} &= 1 \\
\hline
\text{Total} &= 100
\end{aligned}
$$

Pure carbon per day

$$= \frac{114.24 \times 88}{100} = 100.53.$$

Average analysis of part mine pig during time covered by experiments:

|  |  |  | Metalloids absorbed per Unit of Pig |
|---|---|---|---|
| Carbon | 3.5 | per cent | $= 0.035$ |
| Silicon | 3.25 | " | $= 0.0325$ |
| Phosphorus | 1.49 | " | $= 0.0149$ |
| Sulphur | 0.03 | " | $= 0.0003$ |
| Manganese | 1.05 | " | $= 0.0105$ |

Tons taken up per day:

$$\text{Carbon} \quad = \frac{78.23 \times 3.1}{100} = 2.738 \text{ tons.}$$

$$\text{Silicon} \quad = \frac{78.23 \times 3.25}{100} = 2.54247 \text{ tons.}$$

$$\text{Phosphorus} = \frac{78.23 \times 1.49}{100} = 1.1656 \text{ tons.}$$

$$\text{Sulphur} \quad = \frac{78.23 \times .03}{100} = 0.02347 \text{ ton.}$$

$$\text{Manganese} = \frac{78.23 \times 1.05}{100} = 0.821415 \text{ ton.}$$

$$\text{Pure iron} \quad = \frac{78.23 \times 90.68}{100} = 70.9389 \text{ tons.}$$

Oxygen introduced into the furnace by the materials calculated from the pig iron and metalloids, together with the oxygen from the calcium and manganese existing as sulphides in the slag, tons per day:

$$Si + O_2 = SiO_2 = \frac{32 \times 2.5425}{28} = 2.905 \text{ tons.}$$

$$P_2 + O_5 = P_2O_5 = \frac{80 \times 1.1656}{62} = 1.504 \text{ tons.}$$

$$S + O_2 = SO_2 = \frac{32 \times .02347}{23} = 0.02347 \text{ ton.}$$

$$Mn_3 + O_4 = Mn_3O_4 = \frac{64 \times .821415}{165} = 0.3186 \text{ ton.}$$

The oxygen given off by 70.9389 tons of iron as pig iron is taken from an average mixture of the charge; the rates of iron to oxygen

$$= 53.57 : 17.4$$

$$\therefore \text{ tons of oxygen per day} = \frac{70.9389 \times 17.4}{53.57} = 23.041.$$

Oxygen due to sulphides of manganese and calcium in the slag sulphur found in slag = 2.747 per cent, which is equivalent to 1.373 of oxygen.

$$\therefore \frac{1.373 \times 87.561}{100} = 1.201$$

Total oxygen per day:

| | | | |
|---|---|---|---:|
| Oxygen introduced by air | . . . . . . . | | 119.079 |
| " | " | silica . . . . . . | 2.905 |
| " | " | phosphoric acid . . | 1.504 |
| " | " | sulphur as dioxide . | 0.023 |
| " | " | manganese . . . . | 0.319 |
| " | " | calcium, &c., in slag. | 1.201 |
| " | " | iron oxides . . . . | 23.041 |
| | | Total = | 148.072 |

Slag per ton of pig $= \dfrac{87.561}{78.23} = 1.119.$

Fixed matter in flux (dolomite) = 53 per cent
    " carbonic acid . . . = 46 "
    " moisture . . . . . = 1 "

Iron producing materials per day = 133.15 tons, together with 2.5298 of moisture.

$$\text{Carbonic acid from flux} = \frac{50.597 \times 46}{100} = 23.274$$

$$\text{Moisture} = \frac{50.597 \times 0.1}{100} = 0.506$$

$$\text{Fixed matter} = \frac{50.597 \times 53}{100} = 26.817$$

$$\text{Dolomite per day} = \frac{133.15 \times 38\%}{100} = 50.597$$

Estimation of slag per day:

$$
\begin{aligned}
\text{Mineral entering furnace} &= 133.15 \text{ tons.} \\
\text{Fixed matter in dolomite} &= 26.817 \text{ "} \\
\text{10 per cent ash in coke} &= 11.424 \text{ "} \\
\hline
&\ \ 171.391 \text{ "}
\end{aligned}
$$

Deduct from materials entering the furnace the oxygen from metalloids, also that from the calcium and manganese in the slag; in this case the small quantity of dust in gases is estimated as slag.

171.391 less pig iron and oxygen from metalloids, etc.

$$= 171.391 - 83.83 = 87.561 \text{ tons.}$$

Estimation of gases:

$$
\begin{aligned}
\text{Moisture from coke} &= 1.1424 \text{ tons per day} \\
\text{"} \quad \text{" dolomite} &= 0.506 \text{ " "} \\
\text{"} \quad \text{" mineral} &= 2.5298 \text{ " "}
\end{aligned}
$$

Carbon assumed to be gasified by the expulsion of $CO_2$ from flue, according to equation:

$$CO_2 + C = 2CO$$
$$44 : 12 :: 23.274 : 6.347 \text{ tons.}$$
$$\text{Total gas from reaction} = 23.274 + 6.347 = 29.621.$$

Carbon passing through furnace for oxidation in the hearth, etc.

$$= 100.53 - (6.347 + 2.728) = 91.445 \text{ tons.}$$

Carbon gasified to carbon monoxide in lower part of furnace:

$$
\begin{aligned}
\text{Oxygen required} &= 91.445 \times 1.3 = 121.896. \\
\text{Oxygen entering furnace at tuyères} &= 119.079. \\
\text{Deficiency} &= \text{excess of carbon} = 121.896 - 119.079 = 2.817.
\end{aligned}
$$

Total weights of gases:

Oxygen from blast $\qquad$ = 119.079 tons.
  "   due to S in Pig  =  2.905  "
  "   "   $P_2O_5$   =  1.504  "
  "   "   S in slag  =  0.023  "
  "   "   $Mn_3O_4$  =  0.319  "
  "   "   FeO and $Fe_2O_3$  = 23.041  "
  "   "   Ca and Mn in slag =  0.849  "
  "   "   $Co_2$ in dolomite  = 16.927  "
       Total  . . 164.647  "

Carbon in gases:

C in blast as $CO_2$  =  0.007  tons
C introduced less than  97.802  "  in pig iron
C from flux   =  6.346  "
     Total = 104.155  "

Other gases:

H in blast   =  0.4890 tons.
N  "   = 379.2250  "
$H_2O$ in coke  =  1.1424  "
 "  "  dolomite =  0.5060  "
 "  "  mineral  =  2.5293  "
    Total = 382.8922  "

   Grand total = 652.6942 tons per day.

Estimation of the ratio between the carbon oxides. Oxygen required to oxydize C to CO:

$$C + O = CO$$
$$12 + 16 = 28$$
$$12 : 16 : : 104.155 : 138.873.$$
Total CO and $CO_2$ = 104.155 + 164.647 = 268.802 tons.
Excess of oxygen = 164.647 — 138.873 = 25.774.
$CO_2$ in the Gases = O + CO = $CO_2$
$$16 + 28 = 44.$$
$$16 : 44 : : 25.774 : 70.878$$
CO = 268.802 — 70.878 = 197.924
$$\therefore \ CO = 197.924 \text{ tons.}$$
$$CO_2 = \ 70.878 \quad "$$
   Total = 268.802  "

$CO_2$ other than accounted for from dolomite

$$= 70.878 - 23.274 = 47.604.$$

Gases to account for heat generated

$$= 197.924 \text{ CO.}$$
$$47.604 \text{ CO}_2.$$

Oxides of carbon per ton of pig from carbon added to the charge:

$$CO = \frac{197.924}{78.23} = 2.53 \text{ tons.}$$

$$CO_2 = \frac{47.604}{78.23} = 0.6085 \text{ ``}$$

Carbon per ton of pig in CO $= 28 : 2.53 :: 12 : 1.084.$
Carbon per ton of pig in $CO_2 = 44 : 0.6085 :: 12 : 0.166.$
Total combustible carbon $= 1.25$

Ratio of the total carbon in the gases, including that from flux, estimated as $\dfrac{CO_2}{CO}$

Including carbon from flux $= \dfrac{0.24709}{1.084} = 0.2279.$

Not including carbon from the flux $= \dfrac{0.166}{1.084} = 0.1531.$

The calorific values were estimated in the usual way.

---

## THE SYNTHESIS OF BESSEMER STEEL*

By F. J. R. CARULLA, F. C. S.

Derby, England, Manager, in 1874-76, of the Bessemer Department,
John Brown & Co., Ltd., Sheffield

IT is unnecessary to describe the Bessemer process, but it may be useful to have a clear insight of what goes on within the converter, as disclosed by analyses made in 1873.

It is important to note how rapidly the graphite in the pig iron becomes converted into combined carbon as the blowing proceeds and the temperature rises. No analysis of the spiegel used in the above case is available, but the effect of the high temperature of the decarburised iron or blown metal on the spiegel can be seen from the following series of analyses:

It will be seen that in every case the spiegel contained a cer-

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* The Iron and Steel Institute, May (1904) Meeting. Abridged.

TABLE I — *Analyses of a Series of Samples Showing the Changes Undergone by Pig Iron During its Conversion by the Bessemer Process*

|  | Mn. | Graphite. | C. Carbon | Si. | S. | P. |
|---|---|---|---|---|---|---|
| No. 1. The pig iron as it ran from cupola . . | ... | 2·82 | 0·54 | 2·399 | ... | ... |
| No. 2. The same, after blowing 1 minute so as to completely mix . . | 0·324 | 2·72 | 0·64 | 2·426 | 0·117 | 0·044 |
| No. 3. Taken after 11 minutes' blowing . . | ... | none | 2·26 | 1·285 | ... | ... |
| No. 4. Taken after 21 minutes' blowing . . | ... | none | 1·14 | 0·69 | ... | ... |
| No. 5. Taken at the end, after 28 minutes' blowing | trace | none | none | 0·065 | 0·127 | 0·052 |
| No. 6. Steel after adding spiegel . . . . . | 0·649 | none | 0·36 | 0·177 | 0·119 | 0·055 |

tain proportion of graphite, whilst invariably the finished steel only contained carbon in the combined form.

The importance of this fact will shortly be noticed.

*The Spiegeleisen and Ferro-Manganese.* — Spiegeleisen originally came from the Continent, and generally contained a low percentage of manganese — from about five to ten per cent. The manufacture of this material had not long been started in England when the author began his Bessemer practice, and it gradually became the tendency to go on increasing its manganese contents, the demand settling down to anything from 20 to 25 per cent. The consequence was that experience was gained with spiegel of very varying percentages.

Occasionally there would be the disposition to use a spiegel

TABLE II — *Analyses of Three Heats*

| No. of Blow. | Material. | Mn. | Graphite. | C. Carbon | Si. | S. | P. |
|---|---|---|---|---|---|---|---|
| 792 | Blown metal . . | 0·36 | none | none | 0·065 | ... | ... |
|  | Spiegel . . . . | 13·47 | 1·22 | 3·08 | 1·83 | ... | ... |
|  | Steel . . . . | 1·04 | none | 0·30 | 0·056 | ... | ... |
| 793 | Blown metal . . | 0·058 | ... | none | 0·149 | ... | ... |
|  | Spiegel . . . . | 19·30 | 0·46 | 3·86 | 1·34 | ... | ... |
|  | Steel . . . . | 1·08 | none | 0·29 | 0·061 | ... | ... |
| 794 | Blown metal . . | 0·144 | .. | trace | 0·051 | 0·064 | 0·072 |
|  | Spiegel . . . . | 15·60 | 0·80 | 3·34 | 1·77 | ... | .. |
|  | Steel . . . . | 0·83 | none | 0·30 | 0·117 | ... | .. |

with little manganese as pig iron, but this was checked by the knowledge that to put unnecessary manganese into the cupola was unwise owing to its action on the lining.

Every inducement existed therefore to work up the spiegel in its proper place at the end of the process, and that this could be done without detriment, notwithstanding its occasionally containing graphite, the analyses in Table II plainly show.

Table III gives analyses of Continental spiegels such as had been in use before the material was made in England. The fact that such spiegel had been used with perfect success notwithstanding its contents of graphite soon caused one to have the fullest confidence in the English product. Even when this contained as much graphite as the Continental, the proportion in relation to the manganese was generally smaller.

TABLE III — *Continental Spiegeleisen*

| Mark. | Mn | Graphite | C. Carbon. | Si. | S | P. |
|---|---|---|---|---|---|---|
| M | 4 60 | 0·45 | 4·10 | 1·23 | 0·16 | 0·12 |
| S | 5·86 | 0·40 | 4·10 | 0·96 | 0 26 | 0·03 |
| $S_1$ | 6·44 | 0·70 | 3·00 | 0 14 | 0·07 | 0·04 |

*The Carbon.* — The following was the plan adopted to introduce the requisite amount of carbon into the blown metal to make it into the right kind of steel.

An easy calculation will show that:

If $x$ = cwts. of spiegeleisen required,
$C$ = per cent of carbon in spiegeleisen,
$B$ = cwts. of blown metal,
and $n$ = per cent of carbon desired in the steel,

then
$$x = \frac{nB}{C-n}$$

Hence for the ten-ton converters yielding a charge of blown metal weighing 190 cwts., the formula when desiring to produce steel with 0.30 of carbon was:

$$x = \frac{57}{C-0.3}$$

and a handy table was calculated, from which one could see at a glance the weight required for each percentage of carbon contained in the spiegel.

TABLE IV — *Showing Cwts. of Spiegel Required to Produce Steel with 0.30 Carbon in a Charge of Blown Metal of 190 Cwts.*

| Total Carbon in Spiegel. | Cwts. Required. | Total Carbon in Spiegel. | Cwts. Required. |
|---|---|---|---|
| 5    per cent. | 12·12 | 4    per cent. | 15·4 |
| 4·75     ,, | 12·8 | 3·75     ,, | 16·5 |
| 4·5     ,, | 13·5 | 3·5     ,, | 17·8 |
| 4·25     ,, | 14·4 | 3·25     ,, | 18·6 |

This table being for ten-ton converters is of easy modification for those of any other size.

It can be imagined that it was not an easy matter to always dispose satisfactorily, even with the aid of the above table, of such varied materials as those that have been described. One sometimes envied the managers of those rival establishments who obtained something like uniform spiegel or ferro-manganese. Nevertheless, by means of great attention to the bending and the carbon tests, one of which was taken for every blow made, success was achieved.

*The Manganese.* — Now on coming to grips with the synthesis of Bessemer steel the author certainly felt the need of some " key " to the situation that the management of the carbon did not give.

Of course, every one connected with the Bessemer manufacture was aware of the controversy between Bessemer and Mushet, and the important part played by the manganese of the spiegel in the deoxidation of the blown metal. Sir H. Bessemer has himself told how he bought back his first license for £31,500, which one can see was clearly because of the inability of those who took them up to work the process in its original form.[*]

[*] "Journal of the Iron and Steel Institute," 1898, No. I, p. 303.

Without the modification due to R. F. Mushet's ingenuity, namely, the use of spiegeleisen to recarburize, the process was a failure, but the action of the manganese contained in the spiegel was regarded simply as that of a scourer. The aim of the Bessemer steelmakers seemed to be to employ as little as might be of the manganese for the removal of oxygen whilst leaving in the steel all the necessary carbon.

That the manganese did something more than merely clear

the steel of oxygen impressed itself strongly on the author's mind, when on one occasion very good steel was being turned out from one set of converters whilst that from another set was only passable.

The mixtures of pig used are given in Table V, together with the manganese and combined carbon found in the steel.

TABLE  V — *Composition of Charges Used in the Manufacture of Good and of Passable Steel*

| Hæmatite Pig-iron Brand. | Very good Steel. | | Passable Steel. | |
|---|---|---|---|---|
| | Cwts. | Per cent. used. | Cwts. | Per cent. used. |
| Local  .   .   .   . | 10 | 7·7 | 30 | 15·8 |
| Barrow, No. 3  .   . | 30 | 23·1 | 30 | 15·8 |
| West Cumberland   . | 50 | 38·5 | 60 | 31·6 |
| Moss Bay  .   .   . | ... | ... | 20 | 10·6 |
| Cleator   .   .   . | 10 | 7·7 | 20 | 10·6 |
| Swedish   .   .   . | 20 | 15·4 | 20 | 10·6 |
| Mould Scrap   .   . | 10 | 7·7 | 10 | 5·3 |
| | | 100·1 | | 100·3 |
| Mn in the steel .   .   .   . | | 1·17 per cent. | | 0·98 per cent. |
| C. Carbon in the steel .   .   . | | 0·33      ,, | | 0·29      ,, |

The matter was looked at from various other standpoints, such as the greater purity of the Swedish pig iron, the absence of Moss Bay from one of the mixtures, etc., but they were none sufficient to carry conviction as to any of them being the true cause of the mystery. What one, however, may term the " residual " difference remained — namely, the larger amount of manganese present in the very good steel. It was forced upon one that the much better quality of the one steel was due to the slightly greater quantity of manganese that it contained over the other.

The author's experience had been leading up to this, for he had already found that by proper manipulation of the manganese sound ingots free from honeycombs could be obtained. As direct rolling was being introduced, this was a most important matter. By using the exact quantity of spiegel to introduce 1.35 per cent of manganese into the charge, the object was most successfully accomplished.

To satisfy not only the rail-mill manager but also the tire-mill manager, and the forge manager who had to use it for axles, every one of them pronouncing it "the best steel ever made," was enough to make one think that the "key" had at last been found.

And yet some eminent metallurgists have been unable to believe this. The most venerated in this connection, viz., R. F. Mushet, in a private letter to the author, in April, 1884, wrote: "But, and here I expect we shall have to agree to differ, manganese in alloy with steel never did, never can, improve it as steel, and this I shall endeavor to prove when I try in 'Iron' to clear away some cowbwebs, *re* Heath's process and mine."

Not so does H. M. Howe express himself in that monumental work, "The Metallurgy of Steel." He says that in 1872 four distinguished steel metallurgists gave him the figures 0.5, 0.5, 0.75, and one per cent respectively as the highest amount of manganese which should be tolerated in Bessemer rail steel under any conditions whatsoever, but finds that "to-day" (1891) rail steel occasionally contains as much as 2.1 per cent of manganese, and frequently as much as 1.55 per cent.

Now, it is perfectly certain that whilst the proper employment of the manganese, as the author found, is the key to the Bessemer process, still the percentage to be used will depend largely on the composition of the mixtures employed, i.e., on the chemical position of the charge.

*Rail Steel.* — And the question here suggests itself, Are the irregularities of modern Bessemer rails due to direct working from the blast-furnace? It certainly would seem impossible to obtain so regular a product as in the old way, although a 325-ton mixer should do something towards overcoming the difficulty.

But to return to the manganese.

With the mixtures usually employed, analyses of which have been given, it was found that for rail steel so much spiegel should be used as for the manganese to equal 1.35 per cent of the resulting steel, *whatever might be the manganese that remained in the steel.* It will be well for clearness to call this figure the *synthetical manganese,* as the whole of this amount would, of course, not be left in the finished steel, which on analysis might not show more than one per cent.

A table was prepared for the manganese in the same man-

ner as explained for the carbon (see Table IV), and by working
with it steel giving much more uniform mechanical tests than
had been the case before resulted. This was so notwithstanding
that the carbon tests might show considerable differences, cer-
tainly a result that was as surprising as it was welcome, for
working within limits, and not straining the law too far, it was
the easiest thing in the world to regulate the manufacture, in
spite of the great number of strengths of spiegeleisen that had
to be used.

*Steel for Axles.* — Except that a considerable proportion of
Swedish pig was used in the mixture, the synthetical manganese
necessary for axles was practically as when making rail steel,
viz., 1.35 per cent.

The Landore Company, however, was introducing its
" Siemens " steel for this purpose, and some of the railway com-
panies made their tests more severe. For instance, the require-
ments of the Midland Railway Company became that the test
axles " must be capable of standing, without fracture, five blows
from a weight of 2,000 lbs. falling from a height of twenty feet
upon the axle, which shall be placed upon bearings three feet
six inches apart, and turned after each blow."

The axles weighed 430 lbs.

For this purpose the synthetical manganese had to be re-
duced, and just over one per cent was found to produce the
required steel which contained carbon in the neighborhood
of 0.25.

*Steel for Tires.* — Swedish pig iron generally formed part
of the mixture for making tire steel. The synthetical manganese
was 1.25 per cent, as a rule.

*Spring Steel.* — This was the kind of steel where the pres-
ence of carbon above a certain limit became an obvious neces-
sity. No amount of manganese made up for the want of carbon
where the finished product had to be hardened and tempered.
Still there was no difficulty by the choice of suitable spiegeleisen
containing from 15 to 17 per cent of manganese and about five
per cent of carbon to introduce sufficient carbon into the steel
to give perfect satisfaction for the manufacture of laminated
springs. To get 0.45 per cent of combined carbon in the steel
was generally one's aim.

*Conical Springs.* — It was, however, the manufacture of

steel for coiled springs of numerous designs that tried the mettle of the Bessemer manager, as no other occupation could possibly have done.

Every spring, after manufacture, and before it left the works, was tested by dropping a heavy weight upon it from a considerable height, so that the spring was momentarily flattened by the blow into a plain spiral. The spring, if good, resumed its original shape and sent the weight flying up into the air, which falling again upon the spring the action was repeated. This went on a few times with diminishing force and increasing rapidity until the heavy weight came to a standstill. If the steel from which the spring was made was all right, it underwent the ordeal without any damage. If the steel was too soft, the springs became more or less flattened and had to be rejected just as when they broke through the steel being hard. In the technical language of the craft, the springs that became more or less flattened were called " low."

With the success attained in the manufacture of Bessemer steel for the varied requirements of rails, tires, axles, plates, and forgings, it would seem an easy matter to obtain analyses of good and bad springs and go ahead successfully by imitating the good ones. This, however, is easier said than done.

There is no doubt that analysis is indispensable in most modern manufactures; but there are, nevertheless, many points in the synthesis of production that it is very difficult, if not impossible, to discover by anaylsis.

No one will be surprised to learn that the Bessemer converter has been discarded for conical spring steel, which is now made in the Siemens furnace. But the circumstance that already in 1874 it was possible to manufacture so delicate a material by the pneumatic process with the success that was at last achieved, plainly shows that the manufacture of rails with perfect regularity was mere child's play. It is inconceivable that the Bessemer converter should not to-day, or even with the added complications of the basic form, be also able to supply uniform material, whatever modern requirements may be, if only the proper procedure is understood.

## NOTES ON THE PRODUCTION AND THERMAL TREATMENT OF STEEL IN LARGE MASSES *

By COSMO JOHNS
Sheffield, England

WITH a few exceptions, published researches dealing with the heat treatment of steel have been made on a small scale. The author ventures to point out that the conditions in a large works, where the thermal treatment of steel is made a specialty, are very different from those that govern laboratory experiments.

First of all, the mass of the steel that happens to be under treatment plays a most important part, for heat takes an appreciable time in its transmission through the mass, while in a small laboratory specimen the mass plays a very insignificant part. It so happens, however, that the steel products, in whose manufacture heat treatment plays a part, are all of considerable size.

To ensure the homogeneity of a large mass of steel like this is a problem of itself, having regard to the effect segregation of the elements plays in even moderate masses of steel; while to heat equally to a predetermined temperature, and then to cool it at a certain rate, are operations that tax the resources of the metallurgical engineer.

Certain steels are fairly easy to work and to treat in small masses, but when the mass is increased it becomes very difficult. Any attempt to heat or cool them rapidly would result in external or internal fractures. Some alloy steels are even still more difficult to work. When large masses of these are treated, they have to be kept in a heated condition until worked into their final form, and even then losses through fracture or " clinks " are not uncommon.

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* The Iron and Steel Institute, May (1904) Meeting. Abridged.

Then, again, time is a very important factor in thermal treatment. If a small laboratory specimen and a large forging be subjected to the same treatment the resulting structure will be very different, even though the small specimen had been originally a part of the forging and was thus of the same composition.

What was accomplished in minutes with laboratory specimens would take days with large masses. It is well, therefore, that this question of " mass " should be clearly recognized. One of the first lessons learnt in works practice is, that a course of heat treatment eminently suitable for a small specimen as determined in the works laboratory requires to be carefully revised, and the new factors of " mass " and " time " allowed for, before satisfactory results are obtained with large masses.

To " mass " and " time " must be added the " specification," and then we have the chief differences between the problem that presents itself in the works and the results of patient laboratory experiments.

At the River Don works, Sheffield, of Messrs. Vickers, Sons & Maxim, Ltd., are manufactured railway material, such as tires, cast steel crossings, crank and straight axles, etc., marine shafting, forgings and castings for engine parts, finished guns up to the largest size, forgings for gun mountings, projectiles, armor plates, etc., special blooms, billets, bars, etc., of carbon and alloy steels, thus furnishing a varied series of products, the majority of which receive thermal treatment, in one form or another.

*Melting.* — All the steel produced at the River Don works, with the exception of a relatively small portion made by the crucible process, is made in acid-lined, open-hearth furnaces. It has been found that high-class steels, such as those referred to in this paper, used for the manufacture of guns, heavy shaftings, tires, axles, etc., can only be produced satisfactorily by the acid open-hearth process. The chemical purity, by which the author means a low percentage of phosphorus and sulphur, is secured by the careful selection of the materials used. No difficulty is found in obtaining a product under 0.035 phosphorus and sulphur. The object aimed at is to reproduce in the bath as nearly as possible the condition found in " well killed " crucible steel ready for teeming. The addition of aluminium, silicon, and other deoxidizers to the ladle is but an indifferent substitute for good melting. Steel made by the basic process would be quite

unsuitable for the manufacture of the products referred to in this paper.

*Casting.* — The steel is cast in ingot molds of circular, octagonal, rectangular, or square forms, depending upon the purpose for which the ingot is required. Circular molds are rarely used, and then only when the ingots are comparatively short.

The molds are made of cast iron, with an upper portion of non-conducting material, designed so that the body of the ingot may solidify and be fed by the still liquid head. This head, being the last portion to solidify, serves to include the region of segregation, with the result that the top and bottom of the body of the ingots show very little variation in composition. If the entire mold were lined with non-conducting material many of the difficulties encountered in making large ingots in chilled molds would be removed, but there would be the objection that the ingot would solidify more equally over its mass, contraction cavities might be formed in the portion destined for use, while the region of segregation would probably occur there also.

Needless to say, fluid compression is not used. It may seem late in the day to urge objections against the idea, but as in one or two quarters there remains a tendency to see some value in the process, it might be as well to state again the chief objections.

Properly melted steel of the carbon used for products described in this paper contracts in volume when cooling, and, even after the exterior solidifies, the liquid interior still keeps contracting, and on solidification forms internal cavities called pipes. If the ingot mold be properly designed this piping occurs in the head, leaving the body of the ingot quite solid. There will be no blowholes in the body of an ingot made of properly-melted steel of the class we are describing. If there are any, that particular ingot is unfit for use in high-class work, for the walls of the blowholes would not be welded together at the usual forging or rolling temperature. In dead soft steel there does not seem to be the same objection. An ingot free from blowholes is the proof that the steel was properly melted. We have just seen, however, that if the head of the ingot be properly designed, so that it remains liquid longer than the body, it will contain the region of segregation and also the piping. It may now be asked, Of what possible benefit can fluid compression be

to properly melted steel? There are no blowholes to be reduced in volume. The pipe is already in a harmless position, while the volume of the head cannot be reduced without danger of the body of the ingot containing the segregation impurities.

The liquid steel itself cannot be reduced in volume by any practicable pressure any more than water can. The specific gravity of "fluid compressed" steel and *well-melted* steel cast in properly designed open molds is exactly the same. Of course "fluid compression" might serve to mask some of the defects of steel that had been badly melted, by diminishing the volume of the blowholes, but in that case the correct thing would be to scrap the ingot. Fluid compression, therefore, cannot possibly be beneficial to properly melted steel.

*Forging and Rolling.* — It might be mentioned, however, that the correct temperature at which the steel is to be worked in the different departments is secured by the use of pyrometers whenever it appears necessary. The necessary data required for the correct treatment of the steel is supplied by a properly equipped metallurgical laboratory, where microtests are made, cooling curves and critical points worked out, and photomicrographs made. In the chemical laboratory complete analyses are made of every cast of steel made. In the testing department the static tests are made on a hundred ton machine, while vibratory tests are made on a specially designed duplex vibratory testing machine. Working with the quality steels made at the River Don works, the results given by the static tests are found perfectly reliable, and the vibratory tests have only served to confirm that opinion. The various plants for the heat treatment of the steel are capable of dealing with masses 100 feet in length and 100 tons in weight. Having thus briefly reviewed the equipment and methods of manufacture adopted, a description of a few typical products may be interesting.

*Tires.* — High-class tires form one of the special products of the works. The distinguishing feature is that they receive no treatment after leaving the rolls of the tire mill. Whatever structure may be developed must be attributed to careful supervision during manufacture. Great importance is attached to the purity of the materials used, and the steel on analysis must not show more than 0.035 phosphorus or of sulphur. The steel used is regular in composition, and care is taken that at all stages the

work is done on it at the temperature that has been found to give the best results. The tires are allowed to cool in the air after leaving the rolls, and receive no further heat treatment. It is
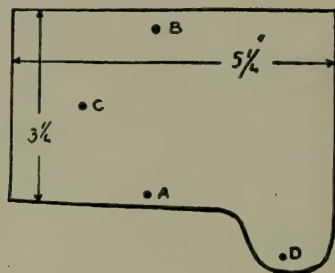


Fig. 1.

considered that, as tires have to be heated when they reach their destination, it would not be prudent to subject them at the works to a course of heat treatment that would possibly be undone when they were being fitted up for use. It will be seen from Figs. 1a and 1b that the tires, though allowed to cool naturally after leaving the rolls, have a well-marked sorbitic structure, and it would be difficult to suggest a treatment that would in any way add to their wearing qualities or increase their resistance to shock. The specifications vary, but a typical one would call for 48 to 56 tons tensile, with a minimum elongation of 15 per cent for 48 tons, and 11 per cent for 56 tons. There is also a drop test in which a " tup " of 2,240 lbs. is allowed to fall freely on
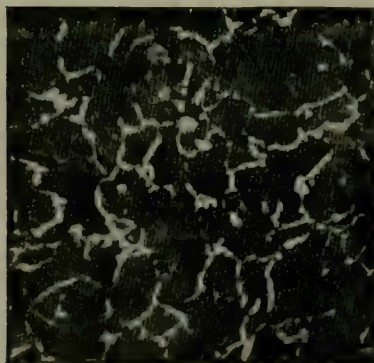


Fig. 2.
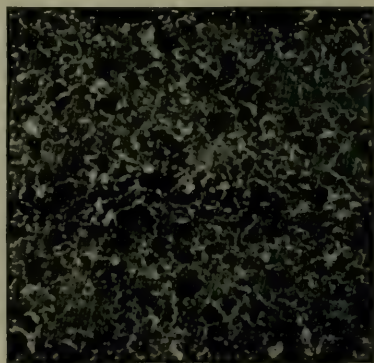


Fig. 3.

the tire (which is placed on a solid metal foundation of at least ten tons weight) from heights of ten feet and upwards, until the deflection of the tire reaches one-sixth of the internal diameter, except when the diameter is less than 36 inches, when the deflection should be one-eighth. The tire should not fail under this test. No difficulty is experienced in meeting these demands, and failure is almost unknown.

The author gives the composition and properties of nine tests, the average of which is given below:

### TABLE I — *"Vickers" Tires*

| Analyses | | Tests | |
|---|---|---|---|
| Carbon | 0.58 | Ultimate Stress, Tons | 52.4 |
| Manganese | 0.76 | Elongation, Per Cent | 15.7 |
| Phosphorus | 0.028 | Reduction of Area, Per Cent | 20.4 |
| Sulphur | 0.030 | | |
| Silicon | 0.196 | | |

*Axles.* — Both the straight and cranked axles are subjected to heat treatment. As in the case of tires, stress is laid on the purity of the steel, 0.035 being the maximum for sulphur and phosphorus. The specifications vary, but a typical one would demand that a test piece to be cut from the axle used for the shock test should give a tensile strength of 32 to 37 tons, with an elastic limit of at least 55 per cent of the ultimate strength. The elongation must not be less than 25 per cent on two inches. The shock test varies with the diameter of the axle.

The following is the average of seven tests described by the author, of specimens oil-hardened at over 1,650° F.:

### TABLE II — *"Vickers" Axles*

| Analyses | | Tests | |
|---|---|---|---|
| Carbon | 0.29 | Yield Point, Tons | 20.6 |
| Manganese | 0.50 | Ultimate Stress, Tons | 36.0 |
| Phosphorus | 0.029 | Elongation in 2 in., Per Cent | 31.8 |
| Sulphur | 0.028 | Reduction of Area, Per Cent | 47.8 |
| Silicon | 0.103 | | |

It will be noted that a relatively high elastic limit and elongation is obtained on a moderate ultimate stress with a fairly low carbon steel.

*Shafts.* — Most of the shafts receive no heat treatment with a view of altering their structure. They are annealed in order to relieve the strains that may be set up during forging.
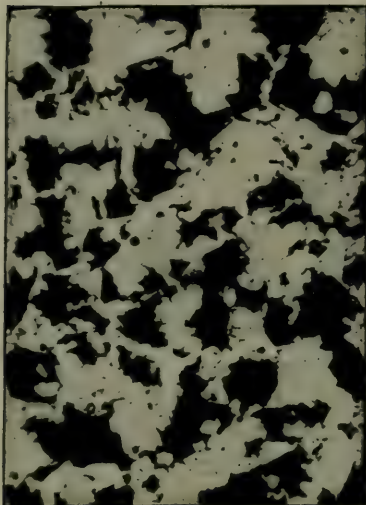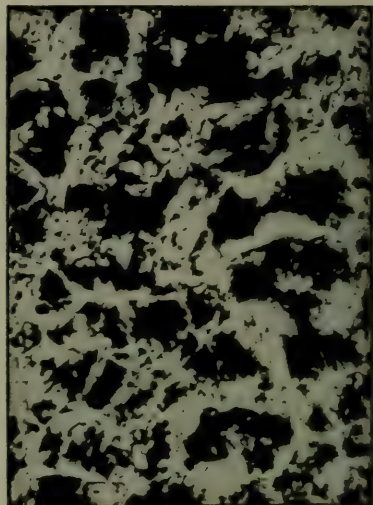


Fig. 4.



Fig. 5.

Shafts annealed at 1,000° F. have the following characteristics (average of five specimens):

### "*Vickers*" *Steel Shafts*

| Analyses | | Tests | |
|---|---|---|---|
| Carbon . . . . . . . | 0.31 | Yield Point, Tons . . . . . | 17.0 |
| Manganese . . . . . . | 0.76 | Ultimate Stress, Tons . . | 32.6 |
| Phosphorus . . . . . . | 0.029 | Elongation in 2 in., Per Cent | 35.0 |
| Sulphur . . . . . . . | 0.030 | Reduction of Area, Per Cent | 51.1 |
| Silicon . . . . . . . | 0.122 | | |

The steel as forged gave the following results:

| Analyses | | Tests | |
|---|---|---|---|
| Carbon . . . . . . . | 0.32 | Yield Point, Tons . . . . | 19.2 |
| Manganese . . . . . . | 0.81 | Ultimate Stress, Tons . . | 35.4 |
| Phosphorus . . . . . . | 0.029 | Elongation in 2 in., Per Cent | 30.0 |
| Sulphur . . . . . . . | 0.031 | Reduction of Area, Per Cent | 43.4 |
| Silicon . . . . . . . | 0.137 | | |

The author gives the chemical and physical characteristics

of 12 forgings for " Vickers " guns, oil-hardened at 1,650° F. and annealed at 900° in order to produce a high elastic limit. The average is given below:

| Analyses | | Tests | |
|---|---|---|---|
| Carbon | 0.30 | Yield Point, Tons | 23.04 |
| Manganese | 0.63 | Ultimate Stress, Tons | 40.98 |
| Phosphorus | 0.029 | Elongation in 2 in., Per Cent | 21.1 |
| Sulphur | 0.028 | | |
| Silicon | 0.118 | | |

Small forgings, cooled rapidly in air, had the following composition and properties (average of four samples):

| Analyses | | Tests | |
|---|---|---|---|
| Carbon | 0.40 | Yield Point, Tons | 19.75 |
| Manganese | 0.85 | Ultimate Stress, Tons | 38.05 |
| Phosphorus | 0.028 | Elongation in 2 in., Per Cent | 29.4 |
| Sulphur | 0.031 | | |
| Silicon | 0.149 | | |
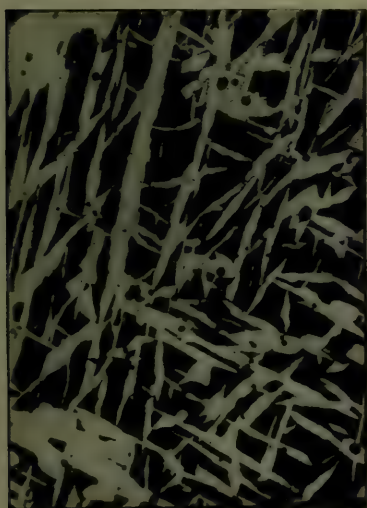


Fig. 6.
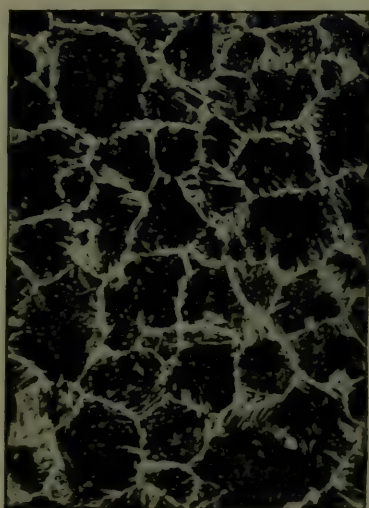


Fig. 7.

*Oil-Hardening.* — That form of thermal treatment known as " oil-hardening " is very interesting, owing to its having been adopted by ordnance manufacturers for a number of years. Long experience has proved that the process gives the structure and special properties required for ordnance steel, and would

also seem to indicate that it still remains the best method of obtaining the desired results. For ordnance work a steel having a high elastic limit is required. This could, of course, be secured by using a higher carbon steel, heating above the critical point and cooling in air, but we have already seen that the difficulty in making large forgings increases with the carbon. Gun tubes are heavy and difficult forgings, but their tubular form, with comparatively thin walls, lends itself to a thermal treatment in which the rate of cooling is considerably accelerated, and the required tests can be obtained easily with a 0.30 carbon steel. The intelligent use of the results given by the chemical and physical tests, enabled the process to be successfully used in past years, and now that more light has been thrown on the structural changes that take place in the steel itself, the methods adopted remain the same. The process is simple enough, though it requires a large plant when long forgings have to be treated. They are raised to a temperature well above the critical range, quickly immersed in oil and allowed to cool. They afterwards are heated to 1,100° F. and allowed to cool slowly. In practice it is better to re-heat the forgings up to 1,100° F. than to stop the rapid cooling at the same point and then to cool slowly. If the forging warps or twists, it is rectified and is then ready for the final machining. The effect of the treatment is to cause a sudden segregation of the carbide of iron, not into the sharply-marked compound crystals of pearlite as in annealed steel, but into more indefinite areas of sorbitic pearlite. These areas are more diffused than would be the case with the pearlite of annealed steel, and would retain some of the hardening carbon, hence the raising of the elastic limit of the steel. It would also appear that the cohesion between the ferrite and sorbitic pearlite is greater than with ferrite and pearlite, probably owing to the line of demarcation being less strongly marked. In any case the steel so treated has a comparatively small grain, gives a high elastic limit with a good percentage of elongation. That these results can be obtained from a steel sufficiently low in carbon to be worked in large masses constitutes the great value of the process to the ordnance manufacturer.

*Vibratory Tests.* — It may have been noticed that endurance tests have not been included in the tabular results given above. The reason is that in no instance have they shown

any want of agreement with the static tests, while the mere recital of the number of revolutions a particular test-piece ran before it broke, would convey no information unless they could be compared with the results obtained on other machines under similar conditions, with the same ratio of load to elastic limit. The endurance is proportional to, and depends upon, the elastic limit.

*Conclusion.* — The author has now briefly reviewed the special products which come within the scope of this paper. It might be objected that the variations in the results are small, but that very regularity is the object aimed for in the works, and its attainment the proof of the correctness of the methods adopted. It would be easy to have extended the tables dealing with tires, axles, guns, shafts, etc., but there would have been the same close agreement between the chemical composition and the tests, having regard to the treatment the steel had undergone. One thing to be emphasized is, that where the steel is to be used in the forms that have just been described, chemical purity is essential. The danger of segregation in large ingots is ever present, though, as the author has shown, it may be diminished by correctly designing the ingot, and can best be minimized by starting with pure materials. The next point is that the steel should be " well killed." It should teem quietly, and remain still and limpid in the molds. The piping should be distinct and blowholes entirely absent. Any attempt to secure this by large additions of deoxidizers to the ladle will only result in great variations in the composition of the steel, while there will be the further difficulty that the oxides thus formed would have no time to rise to the surface, owing to the depth of the steel in the ladle or mold. The effect would be seen in the erratic behavior of the test piece and its discordant results. This is the reason why the basic process is so utterly unsuitable for steel products such as those described here. If the basic process were used, the steel would have to be recarburized and deoxidized outside the furnace, and, as we have seen, this is not suitable so far as high-class steels are concerned. The basic process has its own proper sphere of operation, but the limits of the sphere are very strongly defined. The author next emphasized the importance of casting the steel in open molds with properly designed heads, and of refraining from attempting by extraneous

pressure to compress the fluid steel when the most that could be achieved would be to diminish the volume of blowholes that should never have existed. Lastly, he hopes that he has succeeded in indicating a few of the special conditions that determine, in works practice, the methods adopted for securing the desired results. It has been seen how in tires a suitable structure has been obtained without any thermal treatment, while the remarkable capacity shown by these tires for resisting wear testifies to the correctness of the principles on which their manufacture is based. In axles, gun tubes, etc., oil-hardening is the thermal method adopted; while certain other forgings, possessing as they do a suitable structure when they leave the forge only require annealing from a comparatively low temperature to relieve any strains set up in forging. Other forgings require heating above the critical range, and rapid cooling in air.

## TROOSTITE *

By HENRY COOK BOYNTON, S. M.
Harvard University

THIS paper is a result of a number of experiments which have been pursued in the Metallographical Laboratories of Harvard University. It will, I hope, help to clear up a few facts



in regard to the identity of a constituent, which, although mentioned by several prominent metallurgists, yet has not apparently been generally accepted or understood by the profession as a whole, if one may judge by the lack of published matter.

It was in 1895 that Osmond first mentioned a new constituent which he had discovered and which he named in honor of the emi-

* The Iron and Steel Institute, May (1904) Meeting.

nent French chemist Troost. In his paper first published in the year mentioned above, but now thoroughly revised and brought up to date,* he describes troostite as being a constituent which he obtained by quenching during the critical range.

In detail, his method was to heat a piece of 0.45 carbon steel to 825° C., cool slowly to 690°, and then quench in water at the temperature of the surrounding room. On polishing in "bas-relief," three constituents of varying hardness were discerned; by the "polissage-attaque" the hardest areas were found to be martensite, the soft hollows ferrite, and the intermediate component which enveloped the martensite, which was tinted yellow, brown, blue, or black, he named troostite (see Fig. 1).†

The structure of this troostite Osmond describes as nearly amorphous, slightly granular, and "mammilated." He adds that troostite is also found in hard steel quenched during recalescence, but he shows no photograph of it. Mr. Osmond also says that there is no trouble in distinguishing troostite from martensite, and that the former passes very gradually into sorbite.

Other means of preparing troostite consist (1) in tempering a previously quenched piece of steel, (2) in quenching in oil or boiling water, or in quenching in cold water a relatively large specimen.

According to Osmond, troostite is also found in steel of 0.14 per cent carbon quenched between $Ar_2$ and $Ar_3$,‡ in 1.24 C.‖ and 1.57 C. steel.§ To sum up briefly, he believes that quenching during recalescence, or tempering, transforms "progressively hardenite and austenite (the former more rapidly than the latter), first into troostite and then into sorbite."

Being transitional forms, Osmond states that troostite and sorbite need no place in Roberts-Austen's and Roozeboom's diagram, which illustrates only definite states of equilibrium.

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* "Bulletin de la Société d'Encouragement pour l'Industrie Nationale," May, 1895; "Méthode Générale pour l'Analyse Micrographique des Aciers au Carbone."

† Reproduced from the *Metallogrophist,* vol. iv, p. 281, through the kindness of Professor A. Sauveur.

‡ Société d'Encouragement, 1901; "Contribution à l'Etude des Alliages," p. 305.

‖ *Ibid.,* p. 317.

§ *Ibid.,* p. 318.

The only comment that Osmond makes in regard to the composition of troostite is that it "corresponds to some transitory association between *Beta* iron and carbon."

Following Mr. Osmond's paper, practically no new data in regard to troostite was brought forward for some time; Professor A. Sauveur quotes from Mr. Osmond's paper;[*] the late Sir W. C. Roberts-Austen[†] mentions it, reproducing a photomicrograph, and describes troostite and sorbite as modifications of cementite.

H. Jüptner von Jonstoroff[‡] describes troostite as a "jagged and stringy constituent between martensite and ferrite," and says it "may hold a similar relation to these constituents as
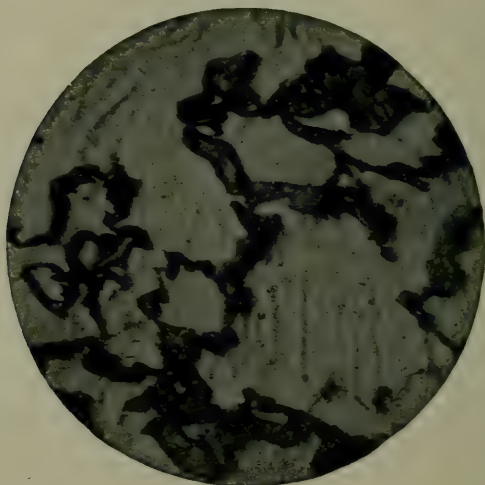


Fig. 1.

sorbite does to ferrite and cementite in pearlite." He adds that "Troostite and sorbite apparently exist only at those temperatures which correspond to the formation of pearlite or to the separation of free cementite, and are retained in the cold metal by sudden cooling from such temperatures."

[*] *The Metallographist*, vol. i, p. 37.

[†] "Proceedings of the Institution of Mechanical Engineers," 1899, p. 35; "Report of the Fifth Alloys Research Committee."

[‡] *Metallographist*, vol. ii, pp. 235-236.

Mr. Osmond, in a later article,* tells us how troostite may be recognized by polishing and etching with nitrate of ammonium by its yellowish-brown or blue bands merging into each other; and it is Osmond again who, in vol. iv of the *Metallographist*,† notes the presence of troostite in the structure of some steel cylinders, the interiors of which had been superficially hardened by explosions of powder. His photomicrograph‡ resembles very closely the troostite obtained by me under very different treatment, and which I shall describe later. Osmond used in this case soft steel, and observes that the troostite in his specimen exhibited a new peculiarity, that of " assuming the shape of needles, recalling the structure of martensite."

On account of criticisms, Osmond later defines a little more clearly his conception of the two constituents, troostite and sorbite. In quenching a piece of carburized iron from a high temperature it passes through the following phases: austenite, martensite, troostite, and sorbite, any one of which may be seen in a sample at the ordinary temperature on quenching during its moment of formation; that is, during the different stages of the period of recalescence.

Osmond says at this time: " Troostite represents a transition form which approaches more than martensite the normal state of equilibrium at the ordinary temperature. Micrographically it can be sharply distinguished from martensite as stated above; between troostite and sorbite, however, there is no well-defined demarcation. . . . Troostite may be produced either by the sudden cooling of steel during the period of recalescence or by a mild quenching (in oil or boiling water, for instance) of small pieces from a temperature higher than that of the critical range, or, again, by a mild tempering of martensite. Sorbite approaches still more to the condition of stable equilibrium at the ordinary temperature. It might be called unsegregated pearlite. Between it and troostite or sorbite there exists no sharp line of demarcation."‖ He adds that although micrographically the three constituents, martensite, troostite, and sorbite, may not be defined as strictly as might be wished, yet they are near enough unlike to demand recognition and to possess different chemical properties.

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* *The Metallographist,* vol. iii, p. 3.
† *Ibid.,* vol. iv, p. 23.　　　　　　　　‡ *Ibid.,* vol. iv, p. 25.
‖ " Bulletin de la Société d'Encouragement," 1900, p. 609.

Professor H. Le Chatelier* also recognizes troostite, and says: " The recalescence phenomenon is not, as we have believed it to be, a simple one. It is in fact a succession of two distinct phenomena: the transformation of pearlite into troostite, and followed by the transformation of troostite into martensite. I ascertained this fact in studying the dilation of steel. A steel containing 0.9 per cent of carbon, on being heated, when it reaches the recalescence point, exhibits a sudden contraction, immediately followed by an expansion of the same magnitude, and amounting to about 0.1 per cent. . . .

" The metal quenched at the beginning of the sudden contraction was found to be made up entirely of pearlite; quenched when the maximum contraction was reached, it was composed almost entirely of troostite surrounding a few particles of pearlite and of martensite; finally, when quenched as soon as it had assumed its normal dimensions, the metal was found to be made up entirely of martensite. . . . I did not obtain any indication concerning the composition of troostite; it is very likely a solid solution, differing from martensite and austenite in being magnetic at its temperature of formation."

Professor A. Sauveur, in the *Metallographist*, gives a brief summary of what has been done in metallography about troostite and sorbite. He goes over the same ground which I have just mentioned, and says, in speaking of troostite and sorbite, that " their existence as structural entities can no longer be contested." He also gives photographs of these two constituents of steel.†

In the Glossary of metallographical terms‡ troostite is defined as follows: " This constituent, according to Osmond, is contained in steels of various carbon contents on quenching at certain temperatures. It is revealed by polishing the steel on parchment moistened with a solution of licorice root or nitrate of ammonia. It readily assumes a brown color by such treatment. It is relatively softer and more rapidly acted upon by acids than martensite. Its composition and molecular construction has not been determined. This is easily recognizable on etching with hydrochloric acid (1 c.c.) in alcohol (100 c.c.). It colors dark while martensite remains entirely unaffected in color.

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* " Bulletin de la Société d'Encouragement," 1900, p. 661.
† *The Metallographist*, vol. iv, p. 279.
‡ " Journal of the Iron and Steel Institute," No. 1, 1902, p. 90.

By reason of the troostite being softer than the surrounding martensite, it has not hitherto been obtained in tangible form." (Martens and Heyn.)

According to the latest researches on expansive properties by H. Le Chatelier, "this is an intermediate formation which occurs on the transformation of martensite into pearlite, and *vice versa*. It is very likely a solution of the carbide $C_3Fe_9$ in iron."

Baron Hanns Jüptner von Jonstorff, in his article in the *Metallographist,* remarks: " Of great interest are Le Chatelier's observations on the expansion of steel and the transformation of troostite. The sudden contraction attending the transformation of pearlite into troostite would account for the diminution of volume which so frequently occurs during the formation of solutions. In like manner it would seem reasonable to assume that the equally sudden expansion which accompanies the transformation of troostite into martensite may be accounted for by regarding troostite as a solution of carbide of iron which is decomposed or becomes depolymerized on its transition into the martensite form; the expansion being due to the increase in the number of existing molecules."

Professor H. M. Howe, in an article on " Iron and Steel " in the " Encyclopædia Britannica," merely mentions the existence of troostite, sorbite, and austenite. In his new book, " Iron, Steel, and other Alloys,"* he barely alludes to troostite, together with martensite and sorbite, saying that " martensite, troostite, and sorbite are transition forms between austenite on the one hand and ferrite and cementite on the other, probably containing all three of these substances, but in varying proportions."

Professor Sauveur adds: " It would seem, moreover, as if the transformation of martensite (solid solution containing 0.80 per cent carbon or less) were not an abrupt but a gradual transformation, the martensite passing through some transitive forms, called by Osmond troostite and sorbite, before assuming the final pearlite condition."†

To summarize briefly the data mentioned above, it appears, then, that:

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* Page 181.

† *The Metallographist,* vol. iv, p. 255; " The Microstructure of High Carbon Steel."

I.  Tróostite may be defined as an intermediate or transitory form between martensite and pearlite.

II.  It may be produced in the cold by:

> (*a*)  The quenching of steel of different carbon contents during the recalescence period — that is, during the time when martensite is undergoing its change to pearlite;
>
> (*b*)  A mild quenching of small pieces from a temperature above the critical point (in oil or in boiling water, for instance);
>
> (*c*)  A mild tempering of martensite.

III.  The formation of troostite on quenching during the recalescence period is accompanied by a sudden contraction indicating a molecular change in the metal (Le Chatelier and von Jonstorff).

IV.  Its composition and properties are doubtful, being given as:

> (*a*)  A modification of cementite (Roberts-Austen);
>
> (*b*)  A solid solution, differing from martensite and austenite by being magnetic at its temperature of formation (Le Chatelier);
>
> (*c*)  "Very likely a solution of the carbide $C_3Fe_9$ in iron" (Glossary);
>
> (*d*)  Mixtures of austenite, ferrite, and cementite in varying proportions (Howe);
>
> (*e*)  Softer than martensite (Osmond).

V.  Its microstructure may be resolved and recognized by:

> (*a*)  Polishing and etching with licorice root or ammonia nitrate, when it assumes a yellowish-brown color, or blue bands merging into each other (Osmond);
>
> (*b*)  Slight etching with dilute tincture of iodine, when it also assumes brown bands in the shape of needles resembling martensite, but surrounding grains of hardenite (saturated martensite), between the grains there being ferrite (Osmond);

(*c*) Its being a jagged constituent between martensite and cementite (von Jonstorff);

(*d*) Etching with hydrochloric acid (1 c.c.), in alcohol (100 c.c.) (Glossary).

It is my intention in the matter following to present some material which will, I think, confirm positively the existence of troostite, and to add some data which has not hitherto been published.

In the course of a number of experiments performed in the Metallographical Laboratory of Harvard University, under the supervision of Professor Albert Sauveur, it was thought that the following experiment would be instructive, and would give valuable data in regard to the various constituents of steel:

Two forged bars of 0.54 per cent carbon steel, ½ in. square in section and 14 in. long, were heated to 900° C., being placed side by side in a gas muffle furnace; they were then allowed to cool slowly in the furnace — (1) to remove all possible evidence of cold work, and (2) to secure a uniformly coarse crystalline structure throughout the entire length of the bars. Any change of structure could then be easily recognized.

These two bars were then held tightly together, and one end was heated in a forge to a white heat, while the other end of the bars was barely warm. Both bars were withdrawn; one of them immediately quenched in cold water, while the other was allowed to cool slowly in air. By proceeding in this way it is perfectly evident that the results of quenching from any possible temperature, from a white heat down, must be found somewhere in the bar. By examining the bar from one end to the other we must necessarily find all the constituents which can possibly be retained in the cold by sudden cooling from any possible temperature. These conditions, therefore, must be excellent for the production of troostite, since a certain portion of the bar must necessarily have been quenched during the critical point.

In the slowly cooled bar we should likewise find all the constituents which are formed in steel by reheating to any desired temperature followed by slow cooling.

An examination of these bars from the hot to the cold end ought to give a continuous picture of a very instructive nature, for in it should be displayed the whole history of the transformations alluded to in this paper.

To facilitate microscopic study of the two bars two longi-tudinal sections from the hot ends of each bar were taken and polished. By taking the first sample one inch in length, and the second two inches, it was possible to get in the latter section all the visible changes in the structure, from above, down through, and below the critical point of the steel.

A continuous picture was taken of each of these two-inch samples, and each showed, as expected, the different changes of structure from above and down through the critical point.

The unhardened piece — that is, the one allowed to cool in air — was etched with strong nitric acid (sp. gr. 1.42) and ruled with a fine hardened needle as shown in Fig. 2 below.
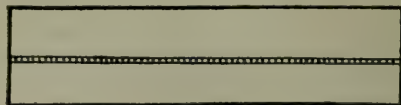
Fig. 2.

The two longitudinal lines and the cross lines were drawn 1/32 of an inch apart, making a number of squares 1/32 of an inch on a side. A picture of each one of these squares was taken on a separate plate, and the prints were cut along the ruled lines, pieced together in order, and mounted on a long cardboard, forming a continuous picture showing all the changes in structure.

It was found difficult to rule the hardened piece by the above method, so that I devised a better plan of marking (Fig. 3).
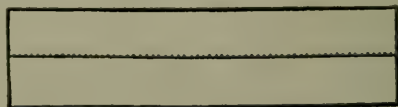
Fig. 3.

One longitudinal line was drawn through the center the whole length of the specimen, and it served as a base line upon which dots were made to locate each photograph. By keeping the base line and dots at one edge of each plate a continuous picture was taken, which, when the different sections were matched together, was perfectly continuous with no divisional line from end to end; it was, therefore, possible to match per-fectly a part of a grain occurring on the divisional part of one plate to its other part on the neighboring section.

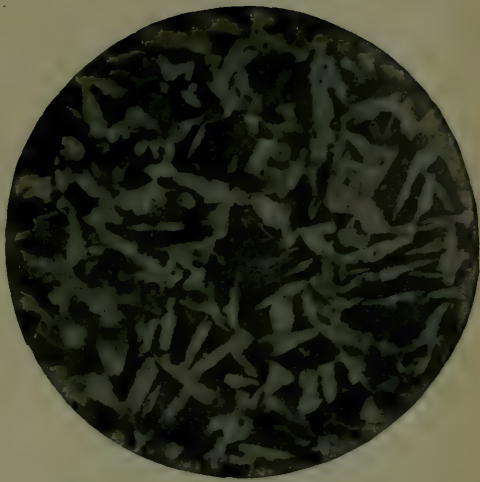Fig. 4. Original Structure. Magnified 1000 diameters.



Fig. 5. Heated to 900° C; cooled in furnace. Magnified 100 diameters.

A number of interesting facts were brought out by these continuous pictures. The original structure of the bars previous to any treatment is given in Fig. 4. It shows a moderately fine structure of the network variety, showing that the bar was forged down to near the critical point, and then allowed to cool in the air, the dark constituent being pearlite and sorbite, and
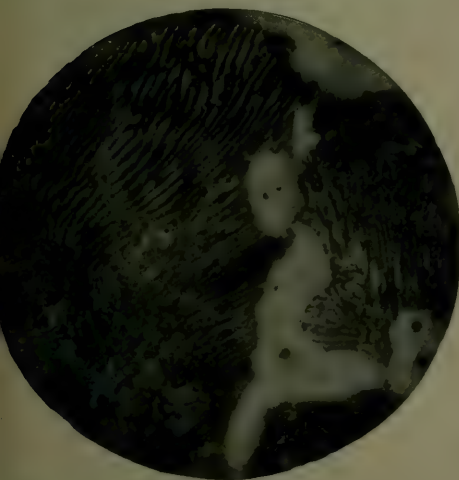


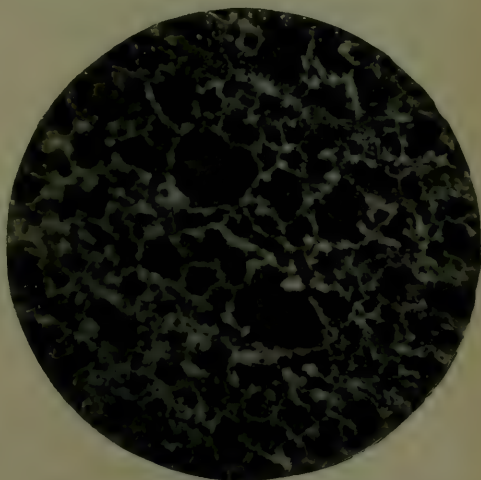Fig. 6. Same as Fig. 5, but magnified 1000 diameters.



Fig. 7. Heated to white heat; cooled in air. Magnified 100 diameters.

the light, ferrite. On heating the two bars to 900° C. and cooling in the furnace nothing new was produced in the line of microstructure (see Fig. 5). Here, however, the network structure has practically all disappeared, being replaced by a coarse structure which, for want of a better name, might be called granitic or granitoid, the dark constituent in this case being all true pearlite, and showing under high magnification the lamellar condition of the eutectic alloy (see Fig. 6).

After heating in the forge as described above, a number of very interesting changes were found to have taken place. Taking up the unhardened piece which was allowed to cool in air from a white heat, on the extreme hot end of the bar a coarse network structure was produced (Fig. 7) which changed very little until near the critical point, which by a number of experiments has been found to be (on cooling) 680° C.

The changes in structure at the critical point could be seen by the naked eye as shown diagrammatically in Fig. 8.

C



Cold end.                                                    Hot end.

P

Fig. 8.

At the dotted line CP a very sudden and marked change took place, the network structure immediately became the granitic although extremely fine (see Fig. 9).

This very fine structure, which is made up of true pearlite and ferrite in very small grains, is the " refined structure " desired in annealing; on proceeding toward the cold end, however, this fine structure very gradually became coarser and coarser until in the actual distance of about an inch from the critical point line, CP, the original coarse structure exhibited in Fig. 5 was attained and continued to the cold end of the bar.

This part of the experiment is simply another instance of the refining of a previously coarse structure by heating to a little above the critical point. So far nothing new has been presented which is not familiar to the average metallographist; the method, however, of obtaining these results and the continuous picture,

which on account of space (the whole series being over six feet long) cannot be reproduced here, has never to my knowledge been brought forward.

The quenched sample is more instructive, and has, I believe, yielded results well worth recording. A number of methods of etching this hardened piece were tried, but the one that seemed to give the best results was a very dilute tincture of iodine, only a very slight application being required.

For about an inch from the hot end of the piece, the only constituent visible was martensite, but from thence a new component was apparent; it appeared brown to black on slight etching, and seemed partially to surround areas of martensite
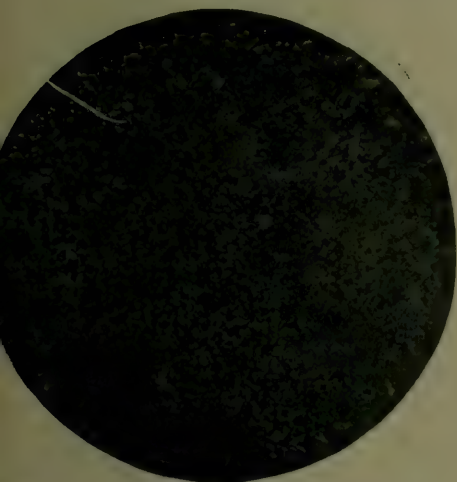


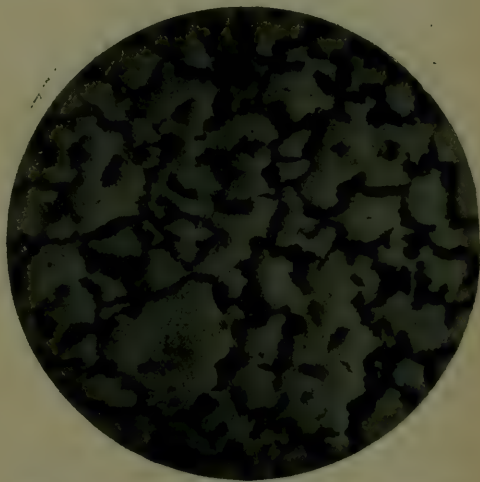Fig. 9.   Refined structure.   Magnified 100 diameters.

Fig. 10.   Troostite and Martensite.   Magnified 100 diameters.

(see Fig. 10). A deeper etching required to bring out the needles of martensite would efface it almost entirely. This new constituent on examination with a low power shows nothing except a sort of jagged network about the martensite; it appears in the section quite suddenly, but at first in a very small amount, which, however, gradually increases on going toward the cold end. This dark constituent is undoubtedly Osmond's troostite. A higher power (Fig. 11) shows the structure of the troostite a little more plainly, and Fig. 12 is the highest magnification that I was able to obtain. The troostite here seems to present a pebbly

appearance, or looks like a mass of irregular dots or globules which Osmond has called "mammilated." That the troostite is softer than the martensite can be easily proved by scratching with a hardened needle; for on ruling the specimen as described above, apparently no impression was made on the latter but a good scratch on the former.

The structure seen in Fig. 10 extends for a space of about an inch of actual distance on the longitudinal section; it varies only a little, but on approaching the cold end the martensite areas gradually decrease somewhat, the troostite proportionally increasing until the latter entirely surrounds almost every grain
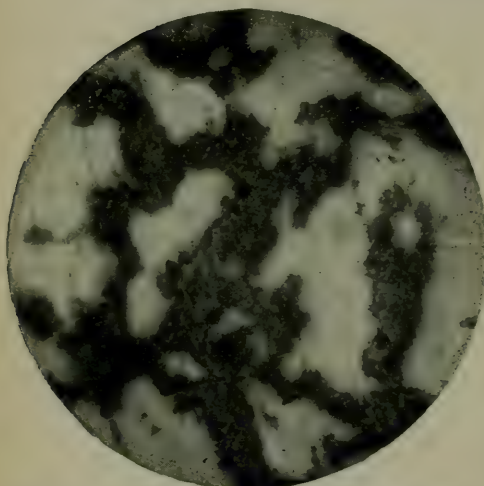


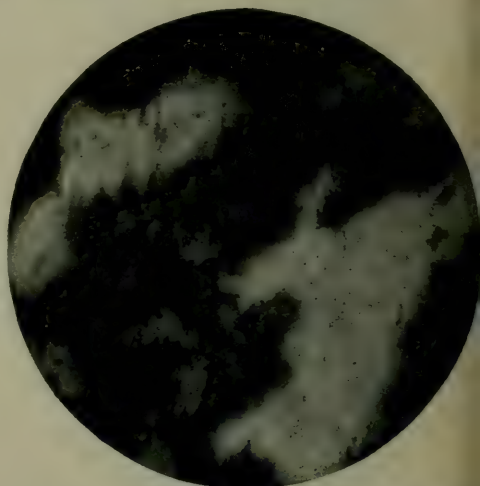Fig. 11.  Troostite and Martensite.  Magnified 250 diameters.

Fig. 12.  Troosite and Martensite.  Magnified 500 diameters.

of the former.  The troostite is not, however, entirely confined to the surrounding areas, particles being frequently seen within the martensite grains (Fig. 11).

A continuous photograph was taken and submitted, a few sections of which showed the greater part of the changes near the critical point.  The first half of this plate showed the troostite at its maximum development, surrounding the martensite which is here hardenite.  In the latter half of the picture, towards the cold end, first appeared a few grains of pearlite; the troostite had not disappeared, and there was still plenty of martensite standing sharply in relief.  The pearlite was represented by the

dark areas increasing in number toward the right half of the picture, which was toward the cold end of the bar.

Fig. 13 shows one of these pearlitic areas under a magnification of 1,000 diameters. The two white areas are martensite; the greyish-white or half-tone surrounding them troostite, and the pearlite is about in the middle of the plate. A portion only of this dark area is true pearlite, the balance being sorbite. The picture is interesting, for here may be found martensite, troostite, sorbite, and pearlite, all the constituents which have a bearing in the discussion, present in one photograph. The martensite in Fig. 13 must, at this stage, be of necessity of the variety
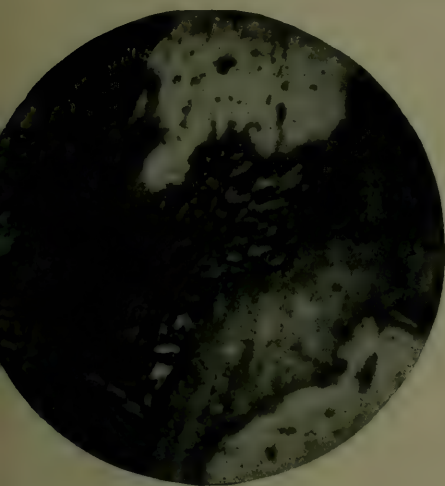


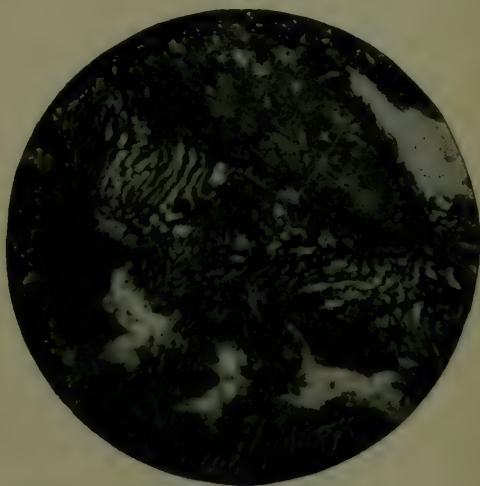Fig. 13.  Martensite, Troostite, Sorbite and [Pearlite].  1000 diameters.

Fig. 14.  [Martensite], Troostite, Sorbite, and Pearlite.  1000 diameters.

hardenite; that is, saturated with carbon, containing about 0.80 per cent of that element.

The extreme cold end of the bar in the continuous photograph shows almost all of the hardenite breaking up into pearlite or sorbite, and the troostite seems to change, but more slowly, into ferrite. Fig. 14 shows a spot of hardenite nearly all transformed to pearlite; no ferrite is apparent in the picture, but the troostite which takes its place is visible and surrounds a large mass of pearlite.

A little further toward the cold end of the bar ferrite appears and rapidly increases in quantity until the original structure of

the bar is reached, consisting of about one-half ferrite and the rest pearlite (see Fig. 15).

Turning now to the nature of troostite, I do not find in the results of these experiments evidences supporting Mr. Osmond's contention that this constituent is a transition form between martensite and sorbite. On the contrary, I am led to take quite a different view of the nature and character of troostite.

When a piece of steel such as I have used in these experiments is allowed to cool from a high temperature, at a certain time it is composed exclusively of martensite: all the iron and all the carbon present in the steel have united to form this con-
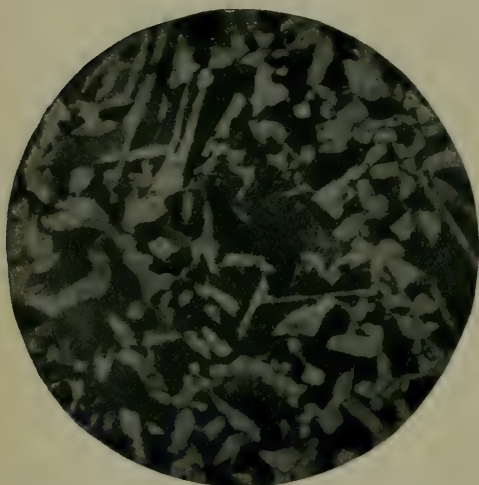


Fig. 15.    Structure below critical point.  Magnified 100 diameters.
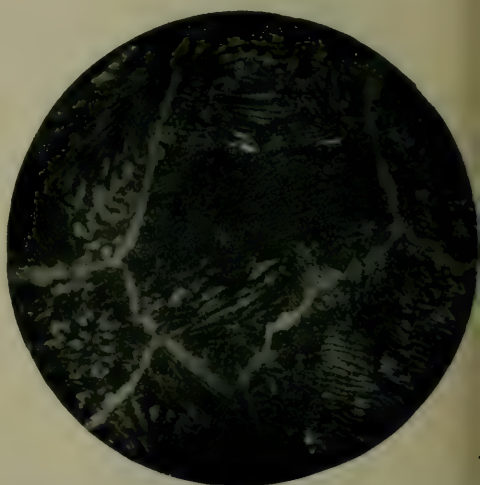
Fig. 16.    Original Structure 1.11 per cent Carbon Steel.   Magnified 250 diameters.

stituent. On further cooling, the martensite gradually rejects some of the iron (ferrite), its carbon content increasing correspondingly until it reaches approximately 0.80 per cent. The martensite is then said to have reached the condition of hardenite. It is now saturated with carbon; that is to say, upon further cooling it ceases to reject any more ferrite but passes to the pearlite condition. In a steel containing about 0.45 per cent of carbon, hardenite should occupy about one-half of the total area, the other half being occupied by carbonless iron (ferrite).

If we now refer to Fig. 10, we find that the martensite (the

white constituent) occupies but a little more than one-half the total area; it has almost reached the hardenite condition, having rejected considerable iron previously included in the martensite. Must not the constituent making up the balance of the field be carbonless iron? Can it be anything else? Is not troostite then the iron first rejected by martensite during the concentration period through which rejection it is eventually converted into hardenite? If it is not this iron, where then is the iron rejected by the martensite? What then is the nature of the martensite seen in Fig. 10?

If troostite is a transition form between hardenite and pearlite it must of course be saturated with carbon; that is, it must contain some 0.80 per cent of that element. In that case the light areas in Fig. 10, which we have naturally considered as martensite, can contain but a slight amount of carbon. Shall we say 0.10 per cent? This martensite, if the name could still be applied to it, should be soft, and in fact the steel itself should not be very hard, while the truth of the matter is, both the light constituent and the steel are *very* hard. If this white component which all metallographists have always considered as martensite, in which the carbon is being concentrated by the rejection of iron, finally reaching the condition of hardenite, is instead a slightly carbonized iron, undergoing still further decarburization, what then is hardenite, and under what possible conditions can this constituent exist? If troostite is a transitory constituent between martensite (or hardenite) and pearlite, then our conception of the nature of martensite, of the mechanisms of the structural changes, of the nature of hardened steel itself, in order to fall in line with this assumption, appears to be inaccurate and calls for revision. Every metallographist will admit that the structure shown in Fig. 10 is a normal structure, which can readily be obtained by using proper precautions. Can it be explained in the light of our present conception of the nature of martensite and troostite?

It seems to me that we have here strong evidence that troostite is some form of carbonless iron. It cannot, however, be *Alpha* ferrite; that is, iron as we find it below the critical point. But is it not *Beta* iron? The mechanism of the formation of troostite would be in accord with our understanding of the allotropic transformation of iron: martensite on cooling rejects *Beta*

iron (troostite), which during the retardation passes to the *Alpha* condition (ferrite), while the saturated martensite (hardenite) is converted first into sorbite and then into pearlite. I find further support for these conclusions in a close examination of the appended photographs (see Figs. 13 and 14), where many indications are found of the passage of hardenite to sorbite and pearlite, and of the troostite into ferrite.

This *Beta* ferrite or troostite is colored dark when first seen, but when viewed with a high power just before its critical change to *Alpha* ferrite takes place, it will be seen to consist of a white or nearly white mass of irregular grains (see Figs. 11 and 12). This different coloration on etching with tincture of iodine may bear out the supposition that the *Beta* ferrite or troostite being in a different molecular state in its arrangement of atoms, might easily be colored differently from the *Alpha* ferrite, the latter not being acted upon at all owing to the very short etching, and remaining bright.

Whether or not troostite is a form of carbonless iron does not, however, call for much speculation, for the theory presented here can readily be proved or disproved. If troostite is, as I am led to believe, some form of carbonless iron, then this constituent should not be formed in an oversaturated steel, since there is then no excess of iron to be expelled by the martensite, no free ferrite in the slowly cooled metal. A piece of 1.11 carbon steel was, therefore, taken and treated as before; that is, heated to 900° C.; allowed to cool slowly in the furnace, and, when cold, one end heated to a white heat in a forge and quenched, the other end of the bar remaining entirely unacted upon. The results confirmed my reasoning, and may be seen in the photographs.

Fig. 16 shows the original structure of the sample before quenching. All the succeeding pictures are from one longitudinal piece about 2 inches in length, which not only shows all the changes in structure through the critical point, but all the common constituents of an ordinary carbon steel. From the hot end through the center to the cold end of the piece the following structures are respectively seen: Austenite and martensite; pure martensite; cementite and martensite; cementite, martensite, and pearlite (small amount); cementite, pearlite and martensite (small amount); cementite and pearlite. On the edges, where a slight decarburization has taken place, may be seen, in addi-

tion to the above, free ferrite and troostite. Also, in a great
many places near the critical point pearlite is replaced by sorbite.

The structural changes which took place were as follows:
Being a supersaturated steel and small in section, the quenching
in ordinary water was sufficiently rapid to produce at the hot
end austenite which may be seen in Fig. 17, and in Fig. 18 at
a higher magnification; on going toward the cold end this
austenite soon gives way to the ordinary needle-like martensite
which is so familiar to all the profession as not to need repro-
duction here. On nearing the critical point, however, the solid
solution of martensite having more carbon than it can carry
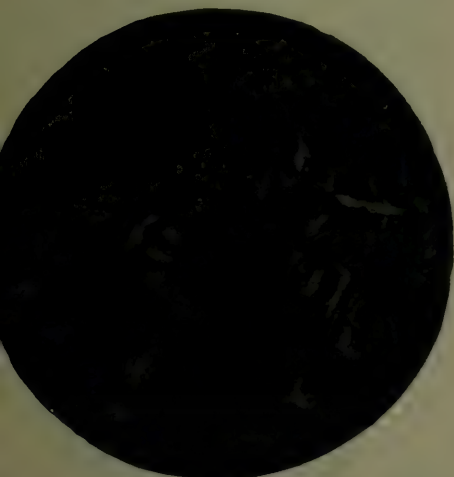


Fig. 17. Martensite and [Austenite?]. Magni-    Fig. 18. Martensite and [Austenite?] Magnified
fied 100 diameters.                                500 diameters.

throws off part of it in the form of cementite (see Fig. 19);
here the martensite has attained the form of hardenite, and the
whole structure exactly simulates the original structure seen in
Fig. 16, with the exception that the pearlite is replaced by hard-
enite, being surrounded or contained within the meshes of a net-
work of cementite. On approaching still nearer the critical point
the network of cementite persists; the hardenite is, however,
dotted here and there with little dark areas made up of pearlite
or sorbite (see Fig. 20). This structure is followed by an almost
complete change of the hardenite to pearlite and sorbite, with

little dots and small white areas of hardenite as islands in the
pearlite. The network of cementite does not change in the least.
Fig. 21, which is a low-power picture, shows the little islands of
hardenite very plainly, and Fig. 22 shows some of the same spots
under a higher magnification, exhibiting the hardenite fading
away or seeming to be dissolved in the surrounding pearlite or
sorbite. The next change in structure is seen in the complete loss
of these small outlyers of hardenite and the recurrence of the
same familiar structure of any hypereutectic steel; that is, of
pearlite and cementite, with more and more of the former assum-
ing its true or lamellar condition, accompanied by a decreasing
amount of sorbite.
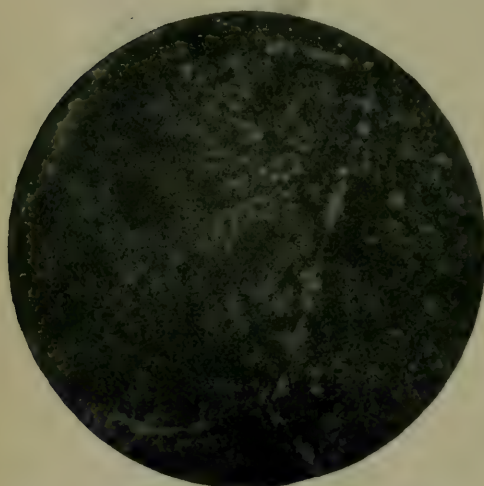


Fig. 19.   Cementite network about Martensite.      Fig. 20.   Hardenite and [Pearlite].   Magnified
             Magnified 500 diameters.                                  500 diameters.
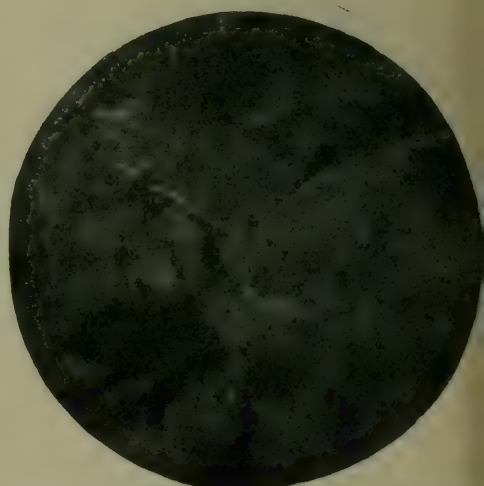
Is not the absence of troostite in a supersaturated steel —
that is, a steel free from ferrite — a most conclusive proof of the
correctness of my views concerning the nature of troostite? If
troostite be a transition form between martensite and pearlite,
it should be found in greater abundance in a high carbon steel,
because of the greater bulk of hardenite which passes to pearlite.

I am well aware that Osmond and Le Chatelier have stated
that troostite may be found in oversaturated steel, but they have
not shown any photographs in support of this contention; and

from the considerations just presented I naturally infer that in those high carbon steels which they have examined they have mistaken sorbite for troostite.

To illustrate further the conclusions I have drawn from the experiments I have presented, the diagrams in Figs. 23 to 25 may be helpful. Fig. 23 represents the change in structure which



Fig. 21. Spots of Hardenite in Pearlite. Magnified 100 diameters.

Fig. 22. Same as Fig. 21, but magnified 500 diameters.

would occur in a piece of 0.45 carbon steel cooled slowly. The structure above the point of recalescence would be composed entirely of martensite (100 per cent), and can be preserved by quenching at that temperature. During the recalescence, since

*Changes in Structure of a Slowly Cooled 0.45 Carbon Steel*

| o | Percentage | | 100 |
|---|---|---|---|
| Just above critical point | Martensite 50 | | |
| During recalescence | Hardenite | Troostite (*Beta* iron?) | |
| Below critical point | Pearlite | 5 o | Ferrite (*Alpha* iron) |
| o | Percentage | | 100 |

Fig. 23.

we have an undersaturated steel, the excess of pure iron or troostite would separate out, and at the end of the period, if this structure be preserved, there ought to be 50 per cent of saturated martensite (hardenite) and 50 per cent of carbonless iron (troostite) ; below the critical point the hardenite has been converted into pearlite and the troostite to *Alpha* ferrite in the same proportion.

With a steel cooled more rapidly we have a slightly different state of affairs; the constituents remain the same, but there is an additional step which must be considered: that of the change of hardenite to sorbite, and of sorbite to pearlite (see Fig. 24).

Fig. 24 is necessary because in a great many forms of steel having a relatively small cross section (steel rails, for example) only a very small amount of true pearlite is found, its place being occupied by sorbite. The reason for the large amount of sorbite formed is because pearlite requires some time for the alternate arrangement of its plates of ferrite and cementite, therefore although above the critical point martensite is found, on a rapid cooling through the period of recalescence, time is denied the martensite to throw off all the carbonless iron it could do if the cooling were slower, and so if the structure found there be made permanent by quenching, more than 50 per cent of martensite would be found, and consequently less than that amount of troostite. No true hardenite could be present, since there

*Changes in Structure of* 0.45 *Carbon Steel More Rapidly Cooled Than in Fig. 24*

| o | Percentage | 100 |
|---|---|---|
| Just above critical point | Martensite (50%+) | |
| During recalescence | Martensite | Troostite |
| Below critical point | Sorbite | Ferrite |
| o | Percentage | 100 |

Fig. 24.

would still be an excess of iron over the eutectic ratio (0.80 per cent), and on further cooling this martensite with an excess of

iron would form sorbite, which has been defined as a " ferrous pearlite," and the troostite would as before become *Alpha* ferrite.

In the case of a supersaturated steel cooled slowly the results are parallel with the slowly cooled undersaturated steel illustrated above (see Fig. 25). Above the critical point, 900° C., for example, martensite is present containing the total carbon dissolved within it; on cooling through the critical point since there is an excess of carbon over 0.80 per cent, this excess carbon unites with some of the iron, and is discarded by the martensite exactly as troostite was discarded in an undersaturated steel. Since there is no free carbonless iron available no troostite or free ferrite can be present, and below the recalescence period the cementite persists, but the hardenite as before changes to pearlite.

On rapid cooling as the cooling of small samples in the air, the martensite should contain more cementite than is necessary to form hardenite, and the structure would vary accordingly. Such a structure ought to possess a higher tensile strength and elastic limit over ordinary pearlitic steel as in the case of " sorbitic steel " over ordinary steel. This latter inference has, moreover,

*Changes in Structure of a Slowly Cooled 1.20 Per Cent Carbon Steel*

| o | Percentage | 100 |
|---|---|---|
| Just above critical point | Martensite 93% | 7% |
| During recalescence | Hardenite | Ce-men-tite |
| Below critical point | Pearlite | Ce-men-tite |
| o | 93 | 7  100 |

Fig. 25.

been verified, and the results will soon be published in a following paper.

It is with some reluctance that I oppose the views of such distinguished and able metallographists as Messrs. Osmond and Le Chatelier, and I hope that if I have erred in my reasoning, criticisms of this paper will promptly bring it out. In order to

disprove the theory advanced, however, it will be necessary to offer satisfactory explanations of some of the points mentioned in this paper, and which, as far as I can see, can only be accounted for on the assumption that troostite is the form first assumed by the carbonless iron rejected by martensite, and which by slow cooling would be converted into ordinary *Alpha* ferrite.

## THE RANGE OF SOLIDIFICATION AND THE CRITICAL RANGES OF IRON-CARBON ALLOYS*

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THE results obtained by previous workers in this field have been embodied by Professor Bakhuis-Roozeboom in his well-known paper,† and our work may be regarded as a test of the accuracy of his conclusions, which are summarized in the following diagram, reproduced from his paper.

The temperatures were measured by thermojunctions. The authors describe at length the precautions taken to secure accurate calibrations of the thermojunctions.
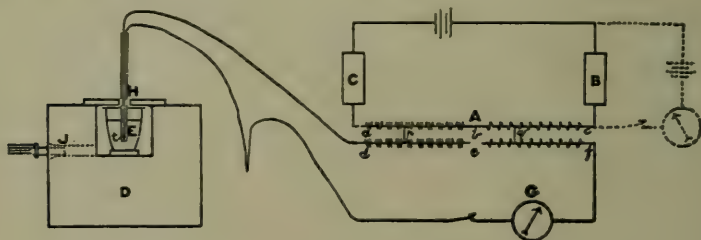


Fig. 1a.

The junctions with the copper were kept at 0° C. by being placed in a box containing melting ice.

*Method of Determining the Range of Solidification.* — The alloys given in Tables I and II were prepared as follows,

the materials being kindly presented at the instrumentality of
Mr. Hadfield, the Hecla Steel Company, Sheffield.

Nos. 2 and 4 were made by melting Swedish charcoal irons..

Nos. 5 and 6 were made by melting samples of " Lilley iron."

Nos. 7-33 were made by melting suitable mixtures of " Lilley
iron " with a Swedish high carbon iron.

No. 34 was made by melting the Swedish high carbon iron.
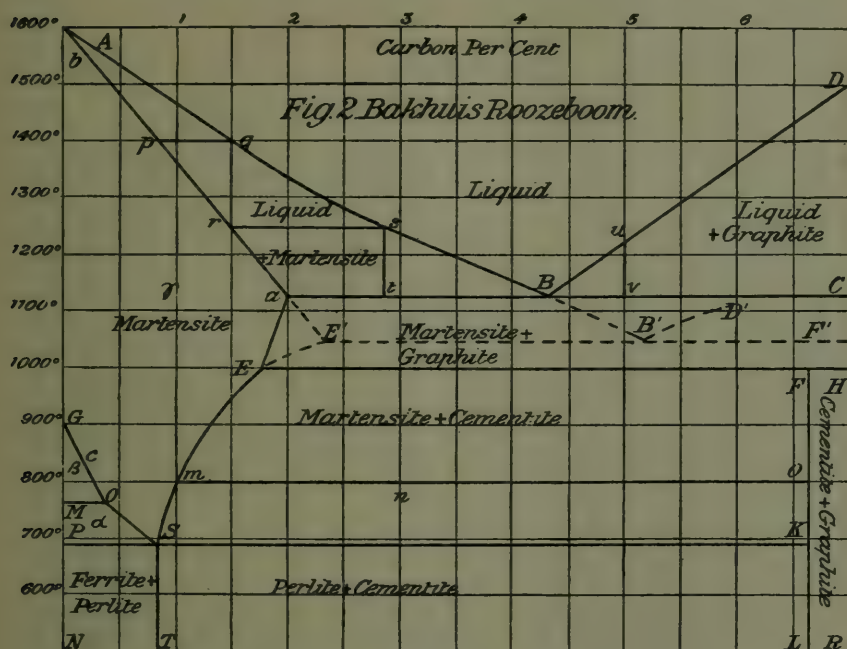


Fig. 1.

No. 35 was made by melting the Swedish high carbon iron
with wood charcoal.

Nos. 36-38 were made by melting the Swedish high carbon
iron with " carburite."

These analyses of these alloys and the materials from which
they were made are given in Table I.

The melting furnace used was a concentric jet crucible fur-
nace capable of taking a No. 3 Morgan crucible (Fig. 1a).

The method of procedure was as follows: From 3 to 4 lbs.
of material were melted down, the crucible being closed by a lid.

*Table I — Tabulated Chemical Analyses of Alloys — Percentages*

| No. of Alloy. | Iron. | Total Carbon. | Graphite. | Silicon. | Sulphur. | Phosphorus. | Manganese. |
|---|---|---|---|---|---|---|---|
| 1 | ... | 0·01 | ... | ... | ... | 0·04 | trace |
| 2 | ... | 0·02 | ... | 0·02 | 0·03 | 0·04 | trace |
| 3 | ... | 0·05 | ... | ... | ... | ... | ... |
| 4 | ... | 0·12 | ... | ... | ... | ... | ... |
| 5 | ... | 0·16 | ... | 0·06 | 0·01 | ... | ... |
| 6 | ... | 0·17 | ... | ... | ... | ... | ... |
| 7 | ... | 0·24 | ... | ... | ... | ... | ... |
| 8 | ... | 0·38 | ... | 0·06 | 0·01 | 0·03 | trace |
| 9 | ... | 0·47 | ... | 0·16 | 0·02 | 0·02 | trace |
| 10 | ... | 0·53 | ... | ... | ... | ... | ... |
| 11 | ... | 0·61 | ... | ... | ... | ... | ... |
| 12 | ... | 0·80 | ... | ... | ... | ... | ... |
| 13 | ... | 0·80 | ... | ... | ... | ... | ... |
| 14 | ... | 0·81 | ... | ... | ... | ... | ... |
| 15 | ... | 0·93 | ... | ... | ... | ... | ... |
| 16 | ... | 1·31 | ... | ... | ... | ... | ... |
| 17 | ... | 1·51 | ... | ... | ... | 0·02 | trace |
| 18 | ... | 1·69 | ... | ... | ... | ... | ... |
| 19 | ... | 1·81 | ... | 0·16 | 0·02 | ... | ... |
| 20 | ... | 1·85 | Nil | 0·09 | ... | ... | ... |
| 21 | ... | 1·97 | Nil | ... | ... | ... | ... |
| 22 | ... | 2·12 | Nil | ... | ... | ... | ... |
| 23 | ... | 2·21 | ... | ... | ... | ... | ... |
| 24 | ... | 2·25 | ... | ... | ... | ... | ... |
| 25 | ... | 2·25 | ... | ... | ... | ... | ... |
| 26 | ... | 2·47 | ... | ... | ... | ... | ... |
| 27 | ... | 2·63 | ... | ... | ... | ... | ... |
| 28 | ... | 2·67 | ... | ... | ... | ... | ... |
| 29 | ... | 2·74 | ... | ... | ... | ... | ... |
| 30 | ... | 2·85 | ... | ... | ... | ... | ... |
| 31 | ... | 3·03 | Nil | ... | ... | ... | ... |
| 32 | ... | 3·29 | 0·14 | ... | ... | 0·02 | .. |
| 33 | ... | 3·42 | 1·80 | ... | ... | ... | .. |
| 34 | ... | 3·51 | 1·38 | ... | ... | ... | ... |
| 35 | ... | 3·87 | 2·14 | 0·06 | ... | ... | ... |
| 36 | .. | 3·98 | ... | ... | ... | ... | ... |
| 37 | ... | 4·37 | ... | ... | ... | ... | ... |
| 38 | ... | 4·50 | ... | 0·12 | ... | ... | ... |
| "Lilley Iron" | .. | 0·1 | ... | 0·06 | 0·01 | 0·02 | trace |
| High Carbon Iron | ... | 4·3 | ... | 0·18 | 0·02 | 0·02 | trace |
| Carburite | ... | 70 | ... | 0·67 | ... | .. | ... |

The time needed for this varied between thirty to thirty-five minutes for the high carbon irons, and about one and a half hours for the lowest carbon irons. If necessary, slag was then skimmed off and the mixture well stirred with a salamander rod. The heating was continued about ten minutes longer, the lid was

then replaced by a fireclay cover with a ½-inch hole drilled through the middle, and the flame turned out. The thermojunction E, enclosed in a fireclay tube closed at the bottom, was inserted through the hole in the cover into the molten fluid, care being taken to place it as nearly as possible in the center and at a distance of about ½ inch above the bottom of the fluid. By this means about 2 inches of the thermojunction wires were immersed. These were insulated from one another by a capillary porcelain tube through which one of them was threaded. The



Fig. 1b.

cold junctions were placed in an ice-box and the wires from here connected with the potentiometer (Fig. 1b).

The cooling of the molten alloy was followed by taking simultaneous observations of temperature and time. By plotting the former as *abscissæ* and the latter as ordinates curves are obtained, three types of which are illustrated on Fig. 2, L, M, and N.

Fig. 2, L, which is the solidification curve of No. 6 alloy, is typical of low carbon alloys of iron. It will be seen that just

above the point at which solidification begins the alloy is cooling at the rate of about 20° C. in fifty-five seconds. A slight recalescence takes place at the moment of solidification in consequence of super cooling. The temperature then falls gradually, about five minutes being taken for the next 20° C. The curve, hitherto concave, upwards becomes a straight line as soon as solidification is finished at about 1,450°, and for the next three minutes the temperature falls about 20° C. in each succeeding forty seconds. After this it becomes convex as the temperature of the alloy gradually regains that of the furnace.
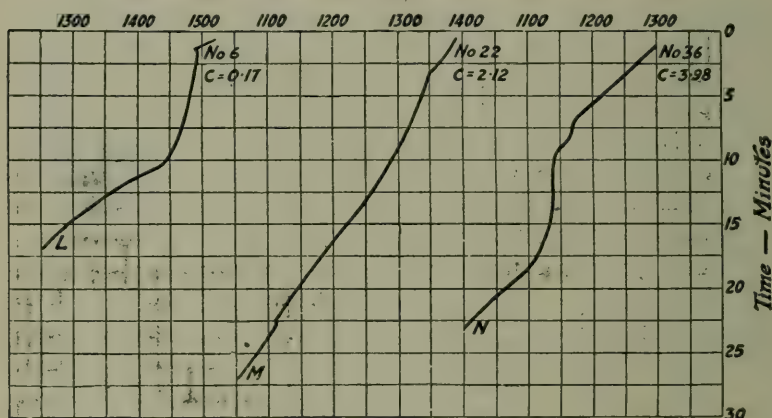


Fig. 2.

Fig. 2, M, the solidification curve of No. 22 alloy, is typical of alloys whose carbon percentage is greater than 2.1. The end of solidification is marked by a recalescence caused by the solidification of the eutectic, containing 4.3 per cent carbon. The range of solidification of this particular alloy is 250° C. — the widest of the whole series.

Fig. 2, N, the solidification curve of No. 36 alloy, is typical of alloys whose composition approaches that of the eutectic, the range of solidification being in this case only 33°.

The results of the observations on the solidifying ranges of the alloys are given in columns 3 and 4 of Table II, and are shown graphically in Plate I.

*Beginning of Solidification.* — The points marking the beginning of solidification lie on a smooth curve, AB, if allowance is

made for experimental errors. The curve is slightly convex upwards, and is represented by the equation

$$t = 1505 - 54.65C - 7.1C_2,$$

where $t$ is the temperature in degrees centigrade, and C is the carbon percentage.

Of the thirty-three alloys the maximum deviation of an observation is 8° C., and in the case of thirty is 5° C. or less. From the curve the following short table has been calculated:

| Percentage Carbon. Pure Iron. | Beginning of Solidification. Degrees Centigrade. |
|---|---|
| 0 | 1505 |
| 1 | 1444 |
| 2 | 1368 |
| 3 | 1278 |
| 4 | 1173 |
| 4.3 | 1139 |

*End of Solidification.* — The end of solidification is shown by the lines A$a$, $a$B. Where the carbon content is above two per cent this is always marked by a recalescence, as noted on page 626, which attains a maximum at 4.3 per cent. The extreme cases are seen in Fig. 2, M and N. In all cases the top of the recalescence has been taken. From 2.1 to 2.5 per cent the temperature appears to rise from about 1,105° to 1,135°; beyond that it is nearly constant.

Where the carbon content is less than two per cent there is no recalescence and the difficulty of interpreting the curves is largely increased. With low carbon content (cf. Fig. 2, L) the change in slope is fairly well marked, and the uncertainty is probably not greater than about 10°. As two per cent carbon is approached the change in slope is less well defined, and the temperatures given are in doubt to the extent of 20° or 30°.

According to the results given the solubilities of carbon in iron at about 1,100° lies between 1.97 and 2.12 per cent. This fully confirms the results obtained by Roberts-Austen and Stansfield.

Only one alloy (C = 4.5 per cent) above the eutectic point has been prepared.

*The Critical Ranges of the Alloys.* — The principle of the method was that introduced by Roberts-Austen and Stansfield,

| Alloy No. | Carbon per Cent. | Range of Solidification Beginning | Range of Solidification End | Ar.m.c. Beginning | Ar3 Beginning | Ar3 Maximum | Ar2 Beginning | Ar2 Maximum | Ar1 Beginning | Ar1 Maximum | Ar0 Beginning | Alloy No. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 0·01 | 1504* | 1470* | | 901 | 900 | 784 | 762 | | | 616 | 1 |
| 2 | 0·02 | ... | ... | | 900 | 890 | 795 | 762 | | | 600 | 2 |
| 3 | 0·05 | 1504† | 1470† | | 905 | 884 | 780 | 762 | | | | 3 |
| 4 | 0·12 | 1498† | 1465† | | 894 | 838 | 774 | 762 | 693 | 688 | 600 | 4 |
| 5 | 0·16 | 1497† | 1450† | | 872 | 837 | 771 | 762 | 697 | 693 | 576 | 5 |
| 6 | 0·17 | 1492† | 1448† | | | Merged | | | | | | 6 |
| 7 | 0·24 | ... | 1416† | | 890 | | | 762 | 696 | 693 | 611 | 7 |
| 8 | 0·38 | 1479† | ... | | | | 778 | 762 | 700 | 699 | | 8 |
| 9 | 0·47 | 1482† | ... | | | | 777 | 762 | | 703 | 587 | 9 |
| 10 | 0·53 | 1473† | 1404† | | | | 762 | 730 | | 700 | 617 | 10 |
| 11 | 0·61 | 1469† | 1394† | | | | 780 | Merged | Merged | 699 | 593 | 11 |
| 12 | 0·80 | 1457‡ | 1351‡ | | | | | | | (704) | | 12 |
| 13 | 0·80 | 1454‡ | ... | | | | | | | (695) | | 13 |
| 14 | 0·81 | 1460† | 1351† | | 774 | Merged | | Merged | Merged | 706 (705) | | 14 |
| 15 | 0·93 | 1443† | ... | | 774 | ,, | | ,, | ,, | 699 | 587 | 15 |
| 16 | 1·31 | 1426† | 1286† | 883 | 774 | ,, | | ,, | ,, | 711 (695) | 600 | 16 |
| 17 | 1·51 | 1406† | 1244† | 911 | 768 | ,, | | ,, | ,, | 713 684 | 587 | 17 |
| 18 | 1·69 | 1388† | ... | 986 | 774 | | | | | 708 710 | | 18 |
| 19 | 1·81 | 1383† | 1179† | (1015) 1030 | 783 | Merged | | Merged | Merged | | | 19 |
| 20 | 1·85 | 1383† | ... | (1042) | | | | | | (711) 711 | | 20 |
| 21 | 1·97 | 1367† | 1110† | | | | | | | (710) | | 21 |
| 22 | 2·12 | 1350† | 1107† | | 801 | Merged | | Merged | Merged | (714) | 610 | 22 |
| 23 | 2·21 | 1364† | 1122‡ | | 801 | ,, | | | | 714 | | 23 |
| 24 | 2·25 | 1352† | 1122† | | 801 | ,, | | | | | | 24 |
| 25 | 2·25 | 1348† | 1134† | | | Merged | | Merged | Merged | | | 25 |
| 26 | 2·47 | 1330† | ... | 1035 | | | | | | (714) | 622 | 26 |
| 27 | 2·63 | 1305† | ... | 1040 | 777 | | | | | 708 | 610 | 27 |
| 28 | 2·67 | 1306† | ... | | | | | | | 716 | | 28 |
| 29 | 2·74 | 1300† | 1139† | 1068 | | Merged | | Merged | Merged | | | 29 |
| 30 | 2·85 | 1292† | 1139† | | | ,, | | | ,, | | 613 | 30 |
| 31 | 3·03 | 1277† | 1139† | | | | | | | | 610 | 31 |
| 32 | 3·29 | ... | 1141† | | | | | | | | | 32 |
| 33 | 3·42 | 1258† | 1114† | 1068 | 790 | Merged | | Merged | Merged | 716 (715) | 610 | 33 |
| 34 | 3·51 | 1230† | 1138† | 1090 | 770 | Merged | | Merged | Merged | 702 (717) | | 34 |
| 35 | 3·87 | 1190† | 1144* | 1087 | | Merged | | | Merged | 703 (714) | 600 | 35 |
| 36 | 3·98 | 1171* | 1138* | | | Merged | | Merged | Merged | (716) 716 | 604 | 36 |
| 37 | 4·37 | 1136* | 1136* | | | | | | | 713 (714) | | 37 |
| 38 | 4·50 | 1146* | 1146* | 1087 | 777 | Merged | | Merged | Merged | 715 | 616 | 38 |

* Thermojunction $M_6$ platinum platinum 10 per cent. iridium.
†    ,,   $M_5$   ,,      ,,       ,,   rhodium.
‡    ,,   $M_4$   ,,      ,,       ,,   rhodium.

The temperatures in brackets in columns 5 and 11 were obtained by direct cooling. All other temperatures in columns 5–12 were obtained by differential cooling.

Ar.m.c. represents separation of massive cementite.
Ar3    ,,    change from γ to β iron.
Ar2    ,,    ,,   β to α   ,,
Ar1    ,,    ,,   hardening carbon to pearlite carbon.
Ar0    ,,    ,,   ,,

viz., differential cooling between the alloy and platinum cooling under the same conditions. The cooling curves have been taken in air. Under these conditions the surface of the metal becomes oxidized, but not to an extent sufficient to mask the critical changes.



Fig. 3a.

The type of furnace made in the laboratory is shown in Fig. 3 and Fig. 3a. It consists of an unglazed porcelain tube 16 inches in length, one inch in diameter, C, heated electrically by a coil of nickel wire, 1.5 mm. diameter, carrying about 20 amperes, and insulated by crushed quartz, Q, contained in a wide porcelain tube, E, closed by furnace-ends, D. The whole was contained in a magnesia steam-pipe covering, M. The wire is wound over the central nine inches of the tube, the distance between the coils gradually increasing from the outside to the center in order to compensate for the cooling effect of the ends. At the thermal center of such furnaces there is usually a space of at least two inches, between 1,000° and 600° C., the temperature variation is not greater than about 3° C. A temperature of 1,000° can be reached with about 740 watts.

Cylinders of the alloys, five-eighths inch long and five-eighths inch in diameter, were turned for the cooling curves. The platinum cylinder, A, was drilled with one hole for the insertion of one end of a differential thermojunction, the other end of which was placed in a hole drilled in the alloy, B. The leads, F, from these were hard-soldered to copper wires placed in an ice-box, and connected with the galvanometer, G. A second hole was drilled in B for an independent thermojunction connected with the potentiometer. With this arrangement galvanometer G indicates differences of temperature between the platinum and the alloy. While the potentiometer gives the actual temperatures of the latter.
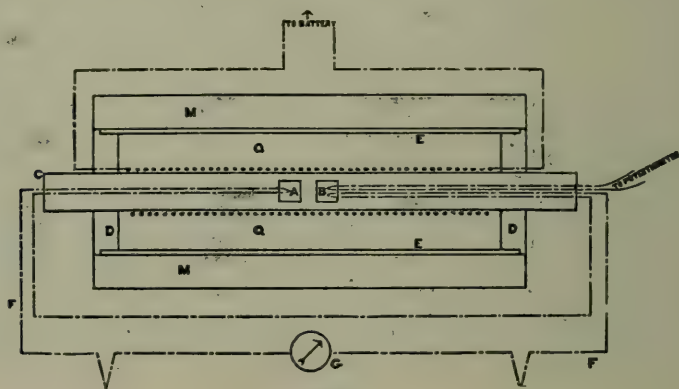


Fig. 3.

At about 1,000° C. porcelain conducts electricity appreciably and accordingly the two cylinders were mounted on a rail made of fused quartz. Several cooling curves were taken from 1,250°-1,300° C., and at these temperatures the quartz devitrifies, and requires to be occasionally reglowed in an oxy-coal-gas flame.

The temperatures from which cooling curves can be taken by this method are limited by those at which the alloys begin to melt. Thus for all alloys above two per cent carbon the limit is fixed at 1,100°-1,140°. The heating of the alloys to this temperature takes about one and one-half hours. Our practice has been to maintain them for about half an hour in this state, in order to allow chemical equilibrium to be reached, and then to cut off the heating current completely. The cooling to 500° C. occupies about one hour and 20 minutes.
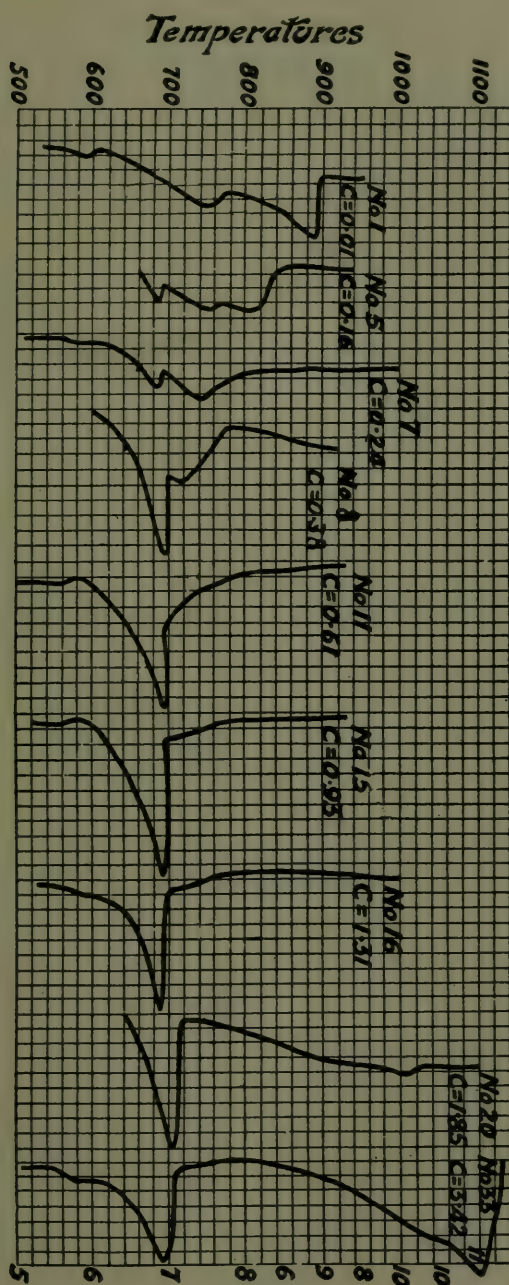
Fig. 4.

In the case of two metal cylinders of equal size, specific heat, and emissivity, and in a uniformly-heated furnace, the cooling curve would, in the absence of critical changes, be a vertical straight line; and if these conditions were not fulfilled, the cooling curve would be a smooth curve approximating to a straight line, but inclined to the vertical. This has been experimentally tested by taking a cooling curve with nickel and platinum as the metals; the curve was inclined to the vertical, and no departure from a straight line was noticeable. This fact has enabled us to interpret with confidence those parts of the curves where small differences of temperature are indicated. It is interesting to note that platinum can be replaced by nickel in the differential cooling method between 1,200° and 500°.

In every case two cooling curves, and sometimes three and four, have been taken, the position of the two cylinders being altered between each cooling curve by moving the quartz rail. In the diagrams the temperature of the alloy is plotted vertically, while movements of the differential galvanometer, caused by differences of temperature between the two cylinders, are plotted horizontally.

Typical cooling curves of nine alloys are appended (Fig. 4). The deflections of the galvanometer connected with the differential junction were in some cases considerable, e.g., at the $Ar_1$ change of alloy No. 15, a movement of 400 millimeters (16 inches) on the scale was recorded. The complete results are given in columns 5-12, Table II. Where possible the beginning and the maximum velocity of heat evolution at each critical change is stated. The former is indicated by the temperature at which the curve begins to change its slope, the latter at which the slope changes from concave to convex. The ends of the critical ranges have not been given, as it appears to us that these depend entirely on the rate of cooling.

Reference to the typical curves shows that the critical changes of the iron-carbon alloys fall into two classes. The changes of the one type are sufficiently rapid to complete themselves within a narrow range of temperature. Instances of these are the $Ar_3$ change in the case of alloys Nos. 1 and 2, and the $Ar_1$ change for all alloys with carbon percentage above 0.3. To these changes the expression " critical point " may be quite properly applied. The other class includes the Ar.m.c. change (the separation of

massive cementite), the $Ar_2$ change, i.e., the appearance of mag-
netism on cooling, and that designated as $Ar_0$. We have never
found that any of these changes occurs rapidly in any alloy. Each
extends over a not inconsiderable range of temperature. It
should further be noted that if the carbon in the alloy is 0.1 per
cent and upwards, the $Ar_3$ change must be removed from the
former to the latter class (cf. curves of alloys Nos. 5 and 7).
In the majority of cases, therefore, critical range expresses the
facts more accurately than critical point.

The various critical changes will now be considered with
reference to Roozeboom's diagram. The fact that we shall con-
sider these in terms of the phases discussed by Roozeboom is not
to be taken as a committal on our part to the adoption of his views.
Plate I gives our results together with his diagram. It should
be stated that the temperature of the beginning of the critical
changes Ar.m.c. and $Ar_0$ has been plotted, but that of the maxi-
mum velocity of $Ar_3$ , $Ar_2$, and $Ar_1$ has been chosen because it
enables a comparison with the results of previous workers to be
more easily made. Further, Ar.m.c. and $Ar_0$ are changes in
which a maximum velocity has not been detected.

*Ar.m.c.* — *Separation of Massive Cementite* — Column 5. —
A typical case is seen in the curve for alloy No. 16, where the
separation begins about 883°. The initial formation of cementite
from the homogeneous solid solution of carbon in iron (marten-
site), i.e. for carbon percentages between 0.9 and 1.7, may be
represented quite as well by a straight line as by the curve given
by Roberts-Austen and Stansfield (Plate V, " Fifth Alloys Re-
search Report "). For carbon percentages between 1.85 and
4.50 the temperature of initial change rises from about 1,030°
to 1,090°. In these cases there is evidence to show that be-
tween 1,140° and the temperature at which martensite and
graphite yield cementite, the solubility of .carbon in martensite
steadily decreases, the separation of graphite being marked by
a steady evolution of heat (cf. curve of alloy No. 20), which,
however, is not sufficient to mask that set free in the formation
of cementite (same curve).

An inspection of the cooling curves does not enable us to
decide whether in all cases the formation of massive cementite
continues progressively until the change from hardening carbon
to carbide carbon takes place at about 710°-715°, the carbon per-

CARBON PER CENT
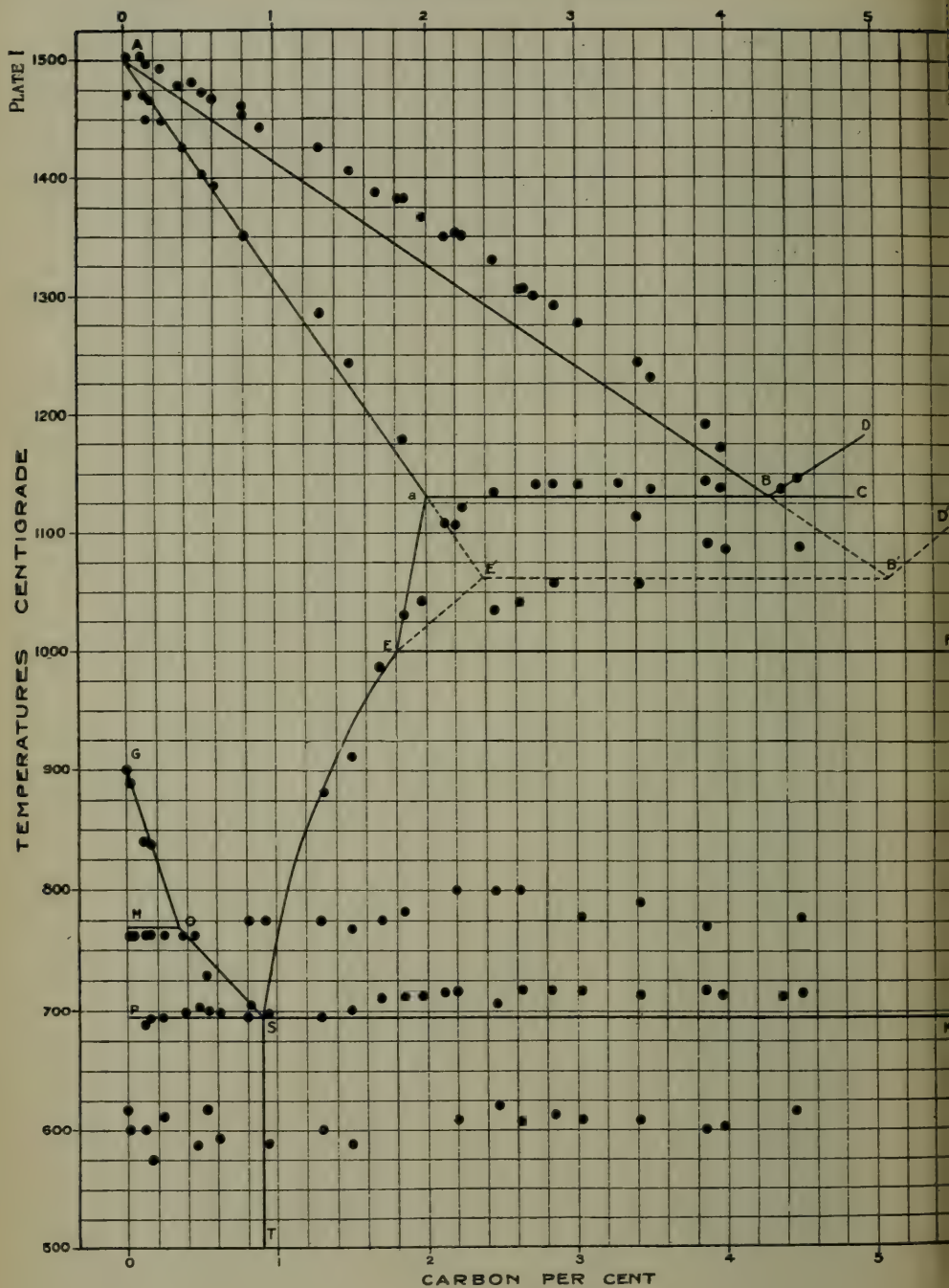
centage of the martensite then being 0.9 per cent. Between 0.9 and 1.85 the continuity of the change is fairly apparent, but for alloys between 2.1 and 4.5 per cent, there are indications in several cases of a slackening or completion of the reaction at about 900° C. In two cases, viz., alloys Nos. 35 and 38, a considerable evolution of heat at about this temperature was noticed. Neither of these facts are explained by Roozeboom's diagram.

In very nearly all alloys, with carbon percentage 0.8 and upwards, a small evolution of heat was noticed at temperatures varying between 770° and 800°. Professor H. Le Chatelier* stated in 1898 that his measurements of the electrical resistances of highly carburetted steel indicated the existence of a change "near 800°," and commented on the fact that if the change occurred slowly it might not cause an appreciable retardation on cooling. Possibly the confirmation of the results of his observations is to be found in this small thermal change.

$Ar_3$ (Columns 6 and 7). — Our results indicate that the temperature at which this change begins is approximately constant, viz., between 900° and 890°; although the maximum falls as carbon percentage rises from 0.01 to 0.24. In agreement with previous workers, we find that in alloy No. 8 (carbon percentage 0.38) $Ar_3$ is merged into $Ar_2$.

$Ar_2$ (Columns 8 and 9). — The temperature of incipient change varies between 795° and 762°; that of maximum velocity of change is constant at 762° for alloys 1-9, and then falls rapidly.

$Ar_1$ (Columns 10 and 11). — The temperature of maximum velocity of change rises gradually, from 688° to 717°.

$Ar_0$. — Our results fully confirm the existence of this change, which was detected by Roberts-Austen and Stansfield,† in pure electro iron and steel containing 0.54 per cent carbon. Its range is, however, hardly so wide as they state, viz., 100° C. It does not appear to us to extend over more than 50° C.

We have investigated the question as to whether this change is associated with an alteration of physical structure. Two sections each were cut from alloys Nos. 1, 8, 14, and 18. The one set was quenched in iced brine from 650°, i.e., before the $Ar_0$ change begins; the other set was quenched from 500°, i.e., after

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* *The Metallographist,* vol. i, 1898, p. 63.
† "Fifth Alloys Research Report," p. 51.

its completion. The sections were polished and etched, Nos. 1 and 8 with five per cent picric acid in alcohol, Nos. 14 and 18 by polish attack on parchment with two per cent ammonium nitrate in water. No differences of structure in any of the specimens were detected.

*Heating Curves.* — In the case of certain alloys, heating as well as cooling curves have been taken, but the former method gives results less well defined than those of the latter. In the appended table Ac denotes change taking place on heating, Ar that taking place on cooling.

*Comparison of Heating and Cooling Curves.*

| Alloy No. | Beginning | | Beginning | |
|---|---|---|---|---|
| | Ar3 | Ac3 | Ar1 | Ac1 |
| 1 | 901 | 908 | ... | ... |
| 2 | 900 | 900 | ... | ... |
| 3 | 905 | 908 | ... | ... |
| 8 | ... | ... | 724 | 724 |
| 20 | ... | ... | 718 | 729 |
| 36 | ... | ... | 728 | 728 |
| 38 | ... | ... | 715 | 728 |

For low carbon alloys, e.g., Nos. 1-3, the temperatures, at which the changes $Ar_3$ and $Ac_3$ begin, appear to be nearly the same. In the case of the changes $Ar_1$ and $Ac_1$ there appears to be a lag of a few degrees.

*Conclusions.* — The results of the experiments are shown by the dots in Plate I, on which is also given the outline of Roozeboom's diagram.

So far as our results go, they confirm, broadly speaking, the accuracy of Roozeboom's diagram, subject to the following qualifications:

1. The melting point of iron is about 1,505° C.
2. AB is a smooth curve, slightly convex upwards.
3. *a*B is not a horizontal line, but rises from *a* to B.
4. SE may be represented quite as well by a straight line as by a curve.
5. PK is not a straight line, but rises from P to K.

Further, our results indicate that the diagram will be amplified in certain parts when the equilibrium between the various phases has been more fully studied, viz., on account of:

1. The small thermal change at about 790° for alloys with carbon content 0.8-4.5;

2. The slow thermal change at about 600° found over the whole range of alloys;

3. The evolutions of heat at about 900° found in alloys Nos. 35 and 38.

Part of the expense of this research has been defrayed out of the grant to the Laboratory from the Iron and Steel Institute.

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# ABSTRACT OF PAPER ON THE RELATIONS BETWEEN THE EFFECTS OF STRESSES SLOWLY APPLIED AND OF STRESSES SUDDENLY APPLIED IN THE CASE OF IRON AND STEEL*

**By PIERRE BREUIL**
**Carnegie Research Scholar, Paris**

THE author is indebted to the generosity of many of the leaders of the iron industry in France for assistance in carrying out his very numerous tests. He has nevertheless been



able to realize only one portion of his programme, and all tests were made at the Laboratory of the Conservatoire National des Arts et Métiers.

The slowly applied, as well as the suddenly applied stresses, whose effect was to be compared, took the form of tensile and bending stresses which were exerted upon ordinary bars, and upon bars which had been specially prepared by notching. It was on account of the widely extended practice in France of making tests on nicked bars that the author decided to try and trace the connection between the deformations occurring in these latter and those which occur in

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* The Iron and Steel Institute, May (1904) Meeting.

ordinary plain bars, and to endeavor to establish the law which governs them.

It seemed to the author that all investigations hitherto made with this object have failed to take sufficient account of the difficulty in which the users find themselves placed, owing to the fact that these new methods of testing have aroused some feeling of distrust of the old methods. He has, therefore, attempted to establish the transition stage between the two systems, having been instigated by the anomalies with which he has frequently been confronted in carrying out tests on nicked bars.

The material employed was supplied in the form of square bars, the sides of which measured 18 millimeters. These consisted (1) of acid open-hearth steel specimens containing 0.7, 0.45, 0.38, 0.125, 0.12, and 0.10 per cent of carbon respectively; (2) of three qualities of steel manufactured in the electric furnace, containing 0.310, 0.515, and 0.600 per cent of carbon respectively; and (3) of wrought iron of various qualities. These materials were also subjected to thermal treatment, which modified their mechanical properties, the three first steels being annealed, the three next quenched and not tempered, while the remainder, including the wrought iron, were not subjected to any previous treatment. The micro-structure of the steels is shown in plates accompanying the paper.

The machines for the slow tensile and bending tests differed in no respect from those usually employed. They were each provided with an indicator which enabled diagrams to be traced, coördinating the stresses with the deformations in the case of all the bars.

The author explains that the object of the idea of notching the bars, which was in order to limit their deformation and show the toughness of the metal by fracturing it across the grain without deforming it if possible, has never been perfectly realized. The various kinds of notching proposed hitherto may, without even testing, be considered open to criticism, for it is immediately apparent that the metal may undergo deformation in spite of every precaution. The notches experimentally tried by the author were made with the saw, with a milling machine, with a drill, and with a lathe, and the difficulties attending the cutting of them are pointed out.

*Slow Tensile Tests.* — For these the notches were made with

the saw and with a milling tool on either side of the tensile test specimens, and the depth varied by one millimeter from one bar to the next, the total range being from 17 millimeters down to five. The notches made with the lathe were left with sharp furrows at the bottom, when the depth was from 17 to 14 millimeters. The diameter of the holes made with the drill was increased a millimeter at a time from two to 12 millimeters.

The diagrams of the tensile tests permit the following conclusions to be drawn, the elongation being measured in a uniform length of 80 millimeters.

1. As long as the section of the notch is not small, the total apparent limit of elasticity indicated by the curves remains the same, whatever the form of the notches. This limit is the same as that of the bars without notches (with certain exceptions which the author explains).

2. The diagrams of tensile strength are all similar but they diminish in height as the notch is deepened.

3. The maximum load of the notched bars referred to the unit of the initial notched section is increased (this accords with the results obtained by other experimenters), but the harder the metal the less is the increase. If this maximum load is referred to the unit of notched section at the moment when this section begins to yield, the value is found to be lower than that of the actual breaking load per square millimeter of the smooth bar. These two values approximate to each other more nearly the greater the depth of the notch.

4. In the case of ductile metal the unit load is higher the sharper the V of the notch. The opposite is the case with the hard steels, which often break from bending. By drilling the notches the unit breaking load may be made to agree more nearly with that of the plain bars.

5. The contraction in the notch diminishes with the acuteness of the V of the latter, but it varies little for the same type of notch.

6. The elongation measured upon the curves before they attain their maximum point of elevation includes that which occurs in the notched section and that which occurs in the smooth part of the bar. The elongation occurring after the maximum point of the curve is reached corresponds to the tear in the notch. This tear, which takes place suddenly in the case of hard steels, is

relatively slow in mild steel and proceeds in much the same manner, whatever the depth of the notch.

7. The maximum point in the curve of the notched bars occurs at the exact moment when the notch begins to crack, and has no analogy with that of the smooth bars except in the ultimate yield point.

8. The amount of work expended in producing the rupture of notched bars is influenced by the two factors contributing to it (the stresses and the elongations), and it consequently varies greatly, according as the type of notch varies.

Summing up, it would appear from these tests to be necessary, in order to arrive at a uniform qualification of all metals from the point of view of tests with nicked specimens, to make the notch in such a manner that the ultimate load in bending should always be less than the limit of elasticity in the smooth portion of the bars. This would involve varying the notch with each kind of metal, for instance, in the case of mild steel, the bars should be nicked to a depth equal to half the initial section, and in that of hard steel, to a depth equivalent to one-third only. If this condition is fulfilled, it may be assumed that the results of the tests upon nicked bars are, in reality, of the same order as those of tests upon plain bars, but much less clear and precise. Under these circumstances, why should the bars be nicked at all.

By experimenting with a series of polished bars the author was enabled, by observing the lines representing the distribution of the deformations described by Hartmann to note that in the nicked bars the deformations began at the point of minimum section under a unit load exactly equivalent to the unit limit of elasticity of the smooth part of the bar. The raising of this limit was only apparent, as one might have been led to expect from the diagrams. The deformation in the neighborhood of the notch is localized in those parts of the bar, the volume of which varies with the notch, which parts, however, are deformed in the same manner if the notch is of the same type. The volume affected by the deformation varies approximately as the square of the distance between the bottom of the two notches when they are cut with a saw or with a milling tool.

In general the fractures of the notched tensile specimens follow the lines of Hartmann, the surfaces at the point of rup-

ture being fibrous or granular, which seems to indicate irregularity in the distribution of the stresses in the metal. The mild steels are the most characteristic in this respect, while the hard steels almost always show a granular fracture, photographs of which are appended to the paper.

*Slow Bending Tests.* — The notches were made with a saw and a milling tool on one side only of the bars, and they were bent on two supports, a distance apart in one instance of 80 millimeters, in the other of 100 millimeters, and the notches varied in depth from one to seven millimeters. For purposes of comparison planed bars of the same metal, having a thickness equal to the nicked bars at the bottom of the notch, were also bent. The results of the test are graphically represented in a large series of diagrams, and may be briefly summarized as follows:

1. All the bending curves for one kind of metal were similar, and as in the case of the tensile tests, the curves for the notched bars are fractions of the curves for smooth bars of the same thickness. A V-shaped notch with a milling tool arrests the curve more quickly than one cut with the saw, but the characteristic outline of the curves remains the same.

2. The curves of the smooth bars show that the limit of elasticity is in accordance with the laws of the resistance of materials.

3. The curves of notched bars reach a maximum at the moment when the first crack manifests itself at the bottom of the notch, but the latter is not completely cracked up to the edges until somewhat later. This point is generally marked by a sudden fall of the curve. The phenomena are particularly clearly marked in the case of mild steel, while with the hard metals rupture takes place at the moment the notch begins to open out. Strictly speaking, mild steels do not break at all even when very deeply notched, so that to classify them exactly is a difficult question.

4. The slightest deviation of the knife edge of the bending press outside the plane of the notch modifies the appearance of the first cracks, and may lead to results which are by no means an indication of the quality of the metal.

5. A very considerable amount of friction occurs between the bars and their supports, which modifies the form of the curves and influences the result of the tests.

6. The contraction of the notched bars diminishes as the notch is enlarged, but only slightly.

7. The work necessary for producing rupture is not without significance, but only in so far as it is applied at the point of notching. Up to the maximum of the curves, however, the work includes that expended in bending the portions of the bar outside of the notched section.

8. The only work which need be taken account of in determining the value of the metal from the point of view of tests with notched specimens is that which is expended after the curves have attained their maximum. But since rupture does not occur in the mild steels it is difficult to obtain an exact criterion.

9. In order to confine the deformation entirely to the notch, care should be exercised to cut less deeply, the harder the metal under investigation, owing to which necessity, however, complications are apt to ensue.

The conclusions to which the author has been led by the study of Hartmann's lines are analogous to those drawn by him from the results of the tensile tests.

The fractures of the bent bars, whether smooth or notched, resemble very much those of the tensile test specimens.

Compared with mild steel, the wrought iron shows a certain superiority in the bending tests with notched bars. The crack successively meets with the laminations which themselves crack and cause the bar to behave much in the same manner as a number of plain bars superposed. The number of bendings and the work expended in the case of the iron are consequently greater than in the case of mild steel.

*Impact Bending Tests.* — All the impact tests made by the author were carried out with a drop-hammer of ten kilogrammes weight. The factors specially investigated were the height of fall and the depth of the notches. The work expended in producing the flexure both of the plain bars and of the notched bars was measured exactly by determining the amount of work in excess. The distance apart of the supports was uniformly 100 millimeters, and by dint of taking a few precautions the tests gave excellent results. After each successive blow of the drop-weight the bars were laid on a sheet of paper, and the set due to the blow was measured. The results of the tests on the plain bars showed that for an *apparently* equivalent amount of work the set

*apparently* diminished when the height of the fall of the drop-hammer was reduced. But on calculating the amount of work expended on the bars and their supports it was found that the same amount of set was produced by the same expenditure of work. This law is general; and, besides, the work performed in dealing the blows is just about equal to the work expended in the slow bending tests. The results with the nicked bars, therefore, lead the author to the conclusion that it is inadvisable summarily to reject the slow bending tests, which have long been established and give more exact results than sudden bending tests.

*Conclusion.* — The conclusion to which the author ultimately arrives is that the nicking of test bars simply implies the introduction of an additional complication, and he questions whether the numerous discussions which have taken place upon this subject can be justified, in view of the fact that the ordinary tensile and bending tests when properly interpreted yield results much less open to criticism than those with nicked bars.

The paper, of which this is an abstract, will be published in the " Journal of the Iron and Steel Institute." It covers about seventy pages, and is accompanied by numerous illustrations and diagrams.

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## EXPLOSIONS PRODUCED BY FERRO-SILICON *

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And CAPTAIN M. B. LLOYD, R. A., H. M.
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I. *Circumstances of the Explosions.* — Having in view the extent to which ferro-silicon is in use, it seems that it is a matter of some importance that the Institute should be in possession of the particulars of several explosions which occurred in connection with a consignment of this material from the Cunard Company's steamship *Veria* at the Alexandria Dock, Liverpool.

The vessel, which had brought a cargo from Triest, was discharged on the 17th December, 1903, and owing, it is said, to

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a fire having occurred on the vessel, the ferro-silicon was detained on the quay until the 12th of January, when Messrs. Beck & Co., of 61 South John Street, Liverpool, removed the forty-eight drums, in which the ferro-silicon was contained, to a warehouse in Dacre Street, Bootle.

They were seen there on a lorry by Inspector Jones of the Explosive Department of the Liverpool Police, whose attention was drawn to them by the strong smell of acetylene gas; this smell, as will be shown, was doubtless due to phosphoretted hydrogen, the unpleasant odor of ordinary acteylene being due to the presence of traces of this gas. Shortly after, whilst a drum was being rolled from the truck on to the concrete floor of the warehouse, a violent explosion occurred followed by flame. The drums were then removed to an open yard, and during this removal a second drum exploded.

It was then considered advisable to place the ferro-silicon in wooden barrels; this was done, and holes were said to have been bored in the end of the casks to prevent the accumulation of any inflammable gas. These measures were, however, of no avail, for on the 21st January a porter employed by the Liverpool Warehousing Company was engaged in weighing some of the barrels and was in the act of removing one from the machine when it exploded. The barrel was blown to pieces, and the man was thrown seven or eight yards away, and being severely bruised was removed to the hospital.

II. *Cause of the Explosions.* — A sample of the ferro-silicon was obtained by us through the head constable of Liverpool, and was submitted to an examination with a view to ascertaining the cause of the explosions. This examination showed that:

The substance when moistened evolved, even in the cold, an inflammable gas which consisted at any rate in far greater part of phosphoretted hydrogen.

Neither acetylene nor siliciuretted hydrogen could be detected, and at most minute traces only of these gases could have been present. (Ferro-silicon yields no siliciuretted hydrogen with water but only when acted on by strong acids.)

For the determination of the cause of this explosion the exact composition of the gas is not a matter of essential importance, the main point is that the gas is inflammable and forms an explosive mixture with air. Experiment has shown that 4 kilo-

grammes of the powdered ferro-silicon will make 64 liters of air explosive. Its temperature of ignition is low, considerably below a red heat; indeed, pure phosphoretted hydrogen ($PH_3$), which is not spontaneously inflammable, is stated to ignite at a temperature of 200° C.

Such a temperature may, we thing, very well be produced by the friction of the irregularly shaped hard lumps of ferro-silicon, either against each other or against the sides of the drum, when subjected to rough treatment.

The experiments were made by one of us with small quantities of finely powdered material; but that brings in mainly the element of time, and moreover in the case of a hard and brittle material like this, a quantity of more or less fine powder is sure to be produced during transport.

The gas evolved by treatment with water ignites when it comes into contact with strong nitric acid. In none of our experiments, however, did the phosphoretted hydrogen evolved inflame spontaneously; it is, however, well known that when produced under certain conditions it is liable to spontaneous ignition.

From these considerations we have therefore formed the opinion that the explosion was most probably caused by water having got into the interior of the drums; the gas evolved formed, with the air in the drums, an easily ignited explosive mixture, which was fired by the heat produced by the friction of the hard lumps against each other when the drums were moved about, or possibly by the spontaneous ignition of some phosphoretted hydrogen contained in a pocket in the material, and liberated suddenly by the breaking of a lump on the drum being moved.

Mr. G. Watson Gray, who read a note on this subject at a meeting of the Faraday Society on the 2nd February,* also attributes the explosion to the presence of phosphorus; but he found acetylene and arseniuretted hydrogen among the gases generated in the casks, though he did not apparently find any acetylene in the gases generated by the sample which he boiled with water in his laboratory.

Mr. Watson Gray, whose experience in metallurgical analysis is well known to the members of this Institute, has kindly

furnished us with the results of his analyses of a piece of the metal.

These are as follows:

|  | Per Cent |
|---|---|
| Silicon . . . . . . . . . | 59.40 |
| Iron . . . . . . . . . | 36.85 |
| Manganese . . . . . . . . | 0.08 |
| Aluminium . . . . . . . . | 2.73 |
| Calcium . . . . . . . . | 0.14 |
| Magnesium . . . . . . . . | 0.17 |
| Carbon . . . . . . . . | 0.218 |
| Sulphur . . . . . . . . | trace |
| Phosphorus . . . . . . . . | 0.056 |

The results of this analysis, when compared with those given by him in his paper on the " Presence of Calcium in High-Grade Ferro-Silicon," * tend to show that the sample was of more than average purity, the percentage of foreign substances being under four per cent, whereas in none of those referred to is that percentage much below seven per cent, and that only with a low proportion of silicon; but it should be noted that although the percentage of calcium is lower, that of phosphorus is higher in this case than they are respectively in any of those reported in Mr. Watson Gray's paper.

III. *Precautions to Avoid Risk in Future.* — It would appear, therefore, that these explosions are probably due, not to the ferro-silicon itself, but to the presence of impurities, and more particularly to the phosphorus compounds contained in it. The best method of avoiding such risks in future would be to use such materials only as are free from phosphorus, or if this be found impossible, to fill up the drums with paraffin oil of high flashing point, or lastly by submerging the finely divided material in water until all action has ceased, and drying the material before packing, as it is improbable that on a large scale every particle of phosphide of calcium or other gas-generating substance would be removed by this latter treatment. The drums used should, as an additional precaution, be perfectly water-tight, and of such strength and construction as not to be liable to become insecure under the ordinary conditions of transport.

An alternative precautionary measure would be only to send

* " Journal of the Iron and Steel Institute," 1901, No. 2, p. 144.

solid ingots well tarred and packed in drums as above described, but we have no means of knowing whether such a measure would be practicable.

Drums suitable for packing the broken ferro-silicon are already in common use for the purpose of packing carbide of calcium, though we should be sorry to be taken to mean that any carbide drum will fulfill the requirements, many of those in use, particularly some of foreign manufacture, being considerably below a desirable standard.

In conclusion, we would point out that although the accident now under consideration was not attended with any very grave results, the possibility of an explosion on a far larger scale must not be lost sight of. It is important, therefore, that all those who have to store or handle this substance should be fully alive to the possible dangers attaching to it, and by keeping it in a dry and thoroughly well-ventilated place prevent the accumulation of inflammable gas as far as possible. We would suggest also that all products of an electric smelting-furnace should be treated with similar precautions until such time as enough is known about them to be certain that these risks do not attach to them.

We cannot conclude without expressing our appreciation of the kindness of Mr. Watson Gray in furnishing us with the results obtained by him and allowing us to use them for the purposes of this paper.

# ABSTRACTS *

**Furnace-Top Explosions.** Frank G. Roberts. "The Iron Age," May 15, 1904. 3,000 w. — The author describes the following peculiar type of explosions:

" In this instance a furnace 70 feet in height was completely emptied of stock down to a point below the cinder notch, surprising as this result may be. Prior to the explosion the furnace had been hanging, but not to an unusual extent. Little damage was done to the furnace; some of the brick work at the top of the furnace was displaced, but the charging apparatus was not injured, while the stock was forced out of the explosion doors and into the dust catcher and gas flues. Apparently this was a furnace-bottom explosion as distinguished from a furnace-top explosion, but the cause seems rather difficult of determination. One explanation is based upon the supposition of a surplus of oxygen in the space below the hanging point; a condition brought about by the fuel in the lower part of the furnace being consumed until there was not sufficient fuel to combine with the oxygen of the blast. Whether this explanation is true is somewhat problematical, but certainly the result of the explosion was remarkable and merits the most careful consideration."

The author reviews and discusses the various theories which have been most prominently advanced to explain fur-

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* NOTE. The publishers will endeavor to supply upon request the full text of the articles here abstracted, together with all illustrations, plans, etc. The charge for this is indicated by the letter following the number of each abstract. — Thus " A " denotes 20 cents, " B " 40 cents, " C " 60 cents, " D " 80 cents, " E " $1.00, " F " $1.20, " G " $1.60, and " H " $2.00. Where there is no letter the price will be given upon request. In all cases the article furnished will be in the original language unless a translation is specifically desired, in which case an extra charge will be made depending upon the length and character of the text.

When ordering, both the number and name of the abstract should be mentioned.

nace-top explosions, and which he classifies as follows: ˙(1) Admission of air to the space above the stock; (2) the deposition of carbon, and (3) the formation of an explosive mixture owing to the absence of sufficient limestone in the burden.

Attempts to control or prevent these explosions are also described in this paper, which is brought to an end in the following words:

" In the light of our present knowledge, it would appear that the following conclusions are warranted:

" 1. That top explosions are not due to the admission of air to the space above the stock in the furnace, and that the occurrence of explosions cannot be ascribed to the presence of explosion doors.

" 2. That the theory which best explains top explosions is the carbon deposition theory.

" 3. That apparently the carrying of a proper percentage of limestone in the burden furnishes a condition which prevents cumulative carbon deposition, and hence, prevents top explosions. Further, that the limestone should be lump stone, and that the required percentage will vary with the character of the stone and ore." **No. 151. B.**

**The Microstructure of Metals.** Percy Longmuir. " Technics," April, 1904. 4,400 w., 12 ill. — " At a meeting in support of technical training, some years ago, one of the speakers, in describing his conversion from the ultra-practical to the scientific aspect, said that when he first heard of chemical methods applied to steel making, his words were: ' What! make steel in a druggist's shop? Never!' But, as the speaker reminded his audience, manufacturers had, by sheer necessity, been compelled to adopt scientific methods of controlling their manufacturing operations. Chemical control of steel making and kindred metallurgical processes is now universal, and practically every metallurgical work is equipped with a works laboratory. Not only have chemical methods taken a firm hold on industrial metallurgy, but to-day a newer and independent form of examination is being adopted by the more progressive works. Chemistry has contributed largely to metallurgical advance; so, too, the material benefits of this newer method — that of microscopical examination of metals — are exceedingly

promising, the results already obtained offering much information of direct practical value. Naturally the results of a microscopical examination are only of value when compared with the chemical composition. Knowing the exact amount of each element present, the next step is to ascertain the mode of existence, or particular method of distribution of these elements in the metal. This is facilitated by the fact that a suitable magnification reveals the structural arrangement, or, as it has been more aptly termed, the internal architecture of the mass.

"The internal structure is not comparable with the appearance presented by a broken surface of the metal, for the method employed to break the metal influences to a large extent the character of a fracture. Further, fractures which to the eye are practically uniform, are often found, when examined at a higher magnification, to be of a very composite character. Fractures do undoubtedly show the general grouping of the crystals, but the particular arrangement and the distribution of impurities are far beyond unaided visual recognition."

The author describes and illustrates the structure of the following metals: Steel, pure copper, copper containing 0.2 per cent of impurity, münz metal, gun metal, pure iron, forged steel, cast steel, white cast iron, gray cast iron and white cast iron after annealing. **No. 152. B.**

**Non-Corrosive Nickel-Steel Boiler Tubes.** Albert Ladd Colby. 11,000 w. — Read at the eleventh general meeting of the Society of Naval Architects and Marine Engineers, New York, November 19, 1903. Boiler tubes made of steel, containing sufficient nickel to make them practically non-corrosive, have recently been successfully manufactured in this country. They were first made abroad in 1898. Tests indicate that they will last two and one-third times as long as mild carbon-steel tubes. This increased strength and non-corrosive properties permit the adoption of lighter gauges than at present in use, thereby increasing the steaming efficiency per pound of fuel and decreasing the weight of the boiler installations. The author discusses his subject under the following headings:

1. Foreign Manufacture and Applications.
2. American Method of Manufacture.
3. Lighter Gauged Nickel-Steel Tubes.
4. Comparative Cost of Nickel-Steel and Carbon-Steel Tubes.
5. Properties of High Nickel-Steel Tubes.
6. Applications of Nickel-Steel Tubes other than for Marine Boilers: Condensers, Superheaters, Stationary Boilers, Automobile Boilers, Locomotive Safe-Ends, Artillery Wagons and Bicycles.
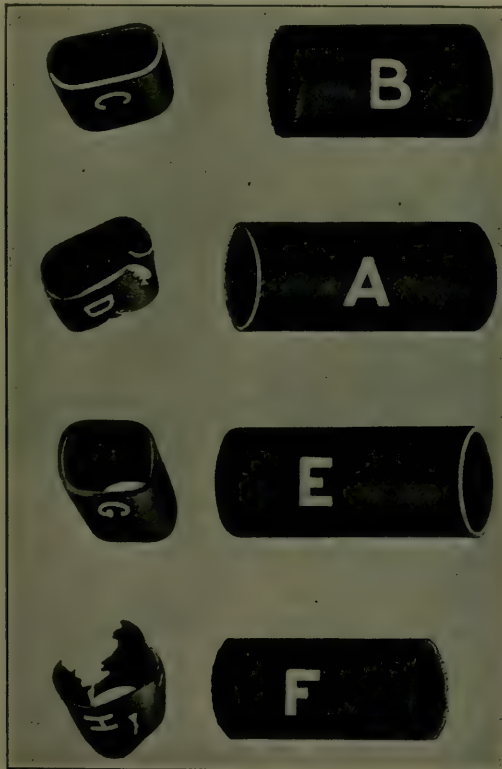


The accompanying illustration exhibits the appearance of nickel-steel and carbon-steel tubes after having been subjected to corrosion tests with acids and to fire tests. Tubes A, E, C and G are nickel steel and the others carbon steel. **No. 153.**

**Vanadium Steel.** " Comptes Rendus," February 8, 1904. — M. Leon Guillet has extended his researches on steels and other alloys to the vanadium-carbon steels which have, up to the present, been the object of only a few investigations, notably by Arnold. Guillet divides these steels into three groups: 1. Those possessing the same structure as ordinary steels (a 0.2 per cent carbon steel showed the pearlite structure up to a content of 0.7 per cent vanadium, a 0.8 per cent carbon steel up to 0.5 per cent vanadium). 2. Those containing in addition to pearlite a special carbide, which is either a carbide of vanadium or a mixed carbide of this element and iron. 3. When the content of vanadium reaches three per cent, both with the low and high carbon, the special carbide constituent is alone seen, all the carbon being taken up by this. The mechanical properties of these steels have also been carefully studied by the author. Those of the first two groups mentioned above have an elastic limit and breaking stress much higher than an ordinary steel of the same carbon content, the elongation is moderate, but they are much harder and more fragile than the corresponding ordinary steel. The steels of the third group have a very low elastic limit and breaking stress, high value for elongation, but despite this they are very fragile. The author considers that the simple vanadium steels are only likely to find use as tool steels; the more complex alloys containing in addition to vanadium such elements as nickel may, however, possess more valuable properties. " Electro-Chemist and Metallurgist," March, 1904. **No. 154. C.**

**Calcining Limestone for use in the Basic Open-Hearth Furnace.** David Baker. " The Iron Age," April 21, 1904. 1,500 w., ill. — A description of the limestone calcining plant at the works of the Dominion Iron and Steel Company. The author prefaces his description by the following remarks:

" Owing to the rapid increase on this continent of the manufacture of open-hearth steel, the necessity has arisen for a substitute for steel and wrought-iron scrap, which is now greatly enhanced in value by reason of the accelerated demand. On this account attention has been directed to the pig and ore process, and because of the low price of non-Bessemer stock the growth of the basic open hearth has been greater than that of the acid process.

: " The several different basic open-hearth processes now in use are the outcome of the effort to reduce the time of the heats and consequently the cost of manufacture. One important factor in this direction is the use of lime instead of raw stone in the process, and is of especial advantage in the pig and ore process." **No. 155. B.**

**The Calculation of the Value of the Raw Material in Pig Iron Making.** A. P. Gaines. " The Iron Age," April 14, 1904. 3,500 w. — The author describes his method in arriving at the relative values of the raw materials in making pig iron. It includes the following determination: Theoretical yield of ore, number of tons of ore necessary to produce a ton of pig iron, cost of ore per ton of pig iron, number of tons of limestone necessary to flux a certain ore required to produce a ton of pig iron, cost of limestone, number of tons of coke required per ton of pig iron, amount of limestone required to flux the coke required per ton of pig iron and form a slag of desired ratio, cost of coke per ton of pig iron, cost of limestone used in fluxing coke, manufacturing and operating cost, total cost per ton of pig iron. **No. 156. A.**

**Meteoric Iron.** F. Osmond and G. Cartand. " Comptes Rendus," December 14, 1903. — The temperature at which the magnetic transformation of iron-nickel alloys takes place is
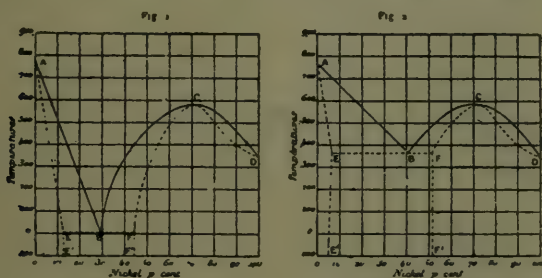


represented by the curves of Figs. 1 and 2, of which the former represents the transition-temperatures observed on cooling, and the latter those observed on heating the alloys. Alloys having a composition from O to E yield unsaturated solutions of nickel in *Alpha*-iron, and are identical with the *kamacite* of

meteoric iron; alloys richer in nickel than F yield unsaturated solid solutions of iron in *Alpha*-nickel and are identical with the *taenite* of meteoric iron; alloys containing proportions of nickel between OE and OF yield mixtures of the two saturated solid solutions of the composition OE and OF; such a mixture occurs in meteoric iron as *plessite*, which is to be regarded as the eutectic alloy of kamacite and plessite.  " Science Abstracts," February 25, 1904.  **No. 157.  C.**

**The Relation of Microstructure to the Rate of Cooling.** W. Campbell.  A lecture to the Philadelphia Foundrymen's Association, April 6, 1904.  " The Iron Age," April 21, 1904. 3,500 w., 3 ill. — The lecturer described the structure of steel, of white cast iron, of alloys of copper and tin, and of copper and aluminium, with special reference to the influence exerted by the rate of cooling.  **No. 158.  B.**

**Life and Diseases of Metals.** E. Heyn.  " Harper's Monthly Magazine," April, 1904.  2,800 w., ill. — A popular, interesting article descriptive of the changes of structure induced in metals by heat treatment and work.  **No. 159.  C.**

**High-Speed Steels.** William Lodge.  A paper prepared for the sixth annual convention of the National Metal Trades Association.  " The Iron Age," April 7, 1904.  2,500 w. — The author discusses the important changes brought about in the construction of machines by the use of high-speed steels.  **No. 160.  B.**

**Method of Welding with Thermit.** " The Iron Trade Review," April 14, 1904.  1,300., 1 ill.  **No. 162.  A.**

**High Temperature Measurements.** L. H. Schutz. " Zeitsch-Vereines Deutsch. Ing.," Jan. 30, 1904.  3,000 w. — Report read before the Lenne Bezirksverein.  A survey of the different instruments that have been proposed for the purpose of the measurement of high temperatures.  **No. 163.  C.**

**Nitrogen in Iron and Steel.** Ernest A. Sjöstedt.  " The Iron Age," May 15, 1904.  3,300 w. — The author describes

the absorption of nitrogen by iron during the process of manu-
facture and the analytical methods which have been devised
for the determination of this gas. **No. 164. B.**

**A Special Bath. Annealing for Toughness.** E. R. Mark-
ham. "American Machinist," April 14, 1904. 900 w., ill. —
The author states that it is sometimes desirable to quench
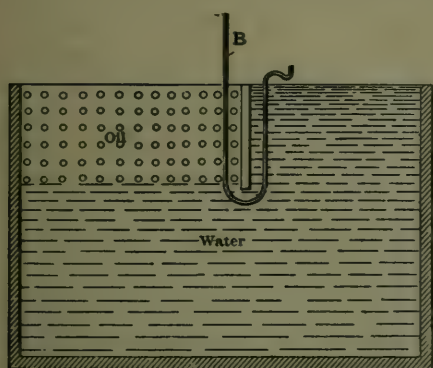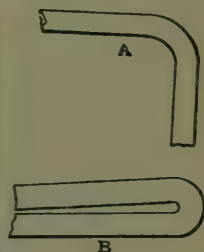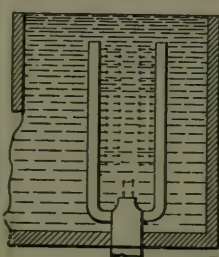articles of steel in a bath of water and before they are cold and



FIG. 1                    FIG. 2

cease contracting to remove them from the water and place
them in oil, and he describes an arrangement of the quenching
bath by which this can be readily accomplished. **No. 161. A.**

**The Electrical Manufacture of Steel.** Gustave Gin. "The
Electro-Chemist and Metallurgist," March, 1904. 600 w., ill. —
A full description of the author's process for the production of
steel by electricity, which consists in heating a thin stream of
metal by the passage of an electric current. **No. 165. B.**

**Manufacture and Use of High-Speed Steel.** "The Iron
Trade Review," April 2, 1904. 4,300 w. — A lecture on the
"Manufacture and use of High Speed Steel," delivered March
4, 1904, by J. M. Gledhill, of the firm of Sir W. G. Armstrong,
Whitworth & Co., of New Castle and Manchester, England,
to the members of the Coventry Engineering Society, Coven-
try, England. **No. 166. A.**

# EDITORIAL COMMENT

A more businesslike effort than ever before is being made to introduce the pig iron warrant system into the warp and woof of the American iron trade. Fifteen years ago a company was organized in the United States to maintain yards for the storage of pig iron and issue warrants therefor. Nearly half a century before the warrant system had been established in Great Britain and had, apparently, done much to steady prices and, under varying conditions, to protect both producer and consumer against loss. As thus instituted, the pig iron storage warrant system can hardly be said to have been a success in the United States. The principle was unfavorably received by producers, while consumers took no particular interest at all.

The friends of the warrant system have lately concluded that interest in pig iron warrants would be encouraged if a market were established for them. Beyond a desultory attempt some years ago to introduce public warrant trading in New York, no effort had been made to encourage dealings in a recognized exchange. In pursuance of this conclusion, pig iron warrants have recently been listed on the New York Produce Exchange, and within the past two months on the New York Metal Exchange and the Pittsburg Stock Exchange. The formulation of rules consumed some time, and it is only within the past three weeks that trading in these exchanges has been regularly authorized.

Among the arguments in favor of a warrant system have been that bidders upon construction work and other contracts requiring a long period of time for their completion would be able to carry warrants for the pig iron involved, and thus protect themselves against loss by an advance in the pig iron market, that in periods of small consumptive demand furnacemen could use warrants as bank collateral instead of forcing the pig iron on an unwilling market, that the pig iron market generally

would be saved from its periods of extreme depression and extreme inflation, and so on. It is obvious that for the realization of such expectations a market for warrants is requisite; prospective consumers of pig iron will be disinclined to purchase warrants if there is no well defined market in which they can buy them at a current price, banks will be indisposed to accept warrants as collateral if there is no market in which they can be easily sold at an approximation to their intrinsic value, and pig iron producers will have little incentive to place any of their iron in storage yards unless the warrants received in return have been given a negotiable value.

These difficulties will be surmounted if warrant trading on the exchanges becomes popular. Those who have been unfriendly to the warrant system make the objection that pure speculation will be introduced and that this speculation will be harmful to the iron trade. It is possible that such fears are not well grounded. Speculation, *per se,* can scarcely be shown to be harmful in any market. The pure speculator is one who sees value in something before others see it, or who sees that something is being held at a higher price than it should be. He acts on his observation, and makes money by doing so. There is no particular harm in this. What is harmful is manipulation, whereby the true relation of things is distorted. The operation of speculation is to establish true values; the operation of manipulation is to disturb them. If trading in pig iron warrants on public exchanges encourages manipulation, then the results to the iron trade will be undesirable, but it is hard to believe that this will be possible. The production of pig iron is so large, and the market so widespread, that it would require operations on an enormous manipulative scale to have any important influence on prices. In times of small demand for pig iron, warrant trading might maintain a market and encourage production, and this is in essence one of the things the opponents condemn, while the proponents favor it as a means of protection to the producer at the time, and protection to the consumer at the later time when an abnormal quantity of pig iron is needed.

# IRON AND STEEL METALLURGICAL NOTES

**American Institute of Mining Engineers.** — The secretary announces that the 87th meeting of the Institute will be held in September next, in the Lake Superior region, particulars of dates, plans and programme to be given in a later circular. It is expected that the arrangements for the Lake Superior meeting will permit a subsequent visit to St. Louis in the last week of September and the holding of a supplementary session at St. Louis, for the official reception of the Institute, and the presentation of papers, etc., calculated to facilitate the study of visiting members of the technical exhibits and departments of the Exposition. In this connection it is announced that a headquarters for members of the American Institute of Mining Engineers and the American Society of Mechanical Engineers will be maintained in the Mining Building under the charge of Professor J. A. Holmes, member of this Institute, and Director of the Department of Mines and Metallurgy of the St. Louis Exposition. The accommodations and facilities of these rooms will be extended freely to all accredited American and foreign engineers.

**International Engineering Congress.** — The following is extracted from a recent circular issued by the secretary of the American Institute of Mining Engineers:

" An International Engineering Congress, organized under the direction of the American Society of Civil Engineers, will hold its sessions in St. Louis, October 3d to October 8th. The list of papers already announced for this Congress is highly interesting, and promises to furnish a summary of recent progress and present practice as to each of the subjects treated. Members of this Institute are heartily urged to promote the success of this Congress by becoming members thereof, through the payment of $5, which will entitle them to the

valuable (copyrighted) proceedings and also, if they are in St. Louis at the time, to attend the sessions of the Congress. Communications on this subject should be addressed to Mr. Charles Warren Hunt, secretary of the committee in charge, 220 West 57th Street, New York City."

**American Society for Testing Materials.** — The Seventh Annual Meeting of the Society will be held, as previously announced, at Atlantic City, N. J., on Thursday, Friday and Saturday, June 16, 17 and 18, 1904. The headquarters will be at the Hotel Traymore.

An elaborate program for the meeting is in course of preparation and will be issued at an early date. Due provision will be made for every important interest represented in the Society. The indications are that this meeting will establish a new record in the history of the Society. Members desiring to contribute papers and who have not yet notified the secretary are requested to communicate with him without delay.

In accordance with the provisions of the By-Laws, the Executive Committee appointed a Nominating Committee consisting of Mr. William R. Webster, Chairman, Mr. Charles M. Mills and Mr. Alexander E. Outerbridge, Jr. This committee has reported the following nominations for the ensuing term (1904-06): For President, Charles B. Dudley; for Vice-President, R. W. Lesley; for Secretary-Treasurer, Edgar Marburg; for Member of the Executive Committee, James Christie.

In reporting the renominations of the present incumbents, the Nominating Committee suggested "that the announcement of these nominations to the members of the Society be accompanied by the statement that, while the Committee deems a change of officers inexpedient at this early period of the Society's existence, its action in this instance is by no means to be regarded as a precedent for the future."

**Process for Annealing Steel.** — A recent patent for annealing steel provides for heating in a bath of melted aluminium. The melting point of aluminium is said to be very near the proper heat for the purpose, so the temperature of the metal

is allowed to rise only a little above the melting point and the steel to be annealed is simply submerged in it until it uniformly attains the same temperature. The loss of metal if not overheated is said to be slight and its action upon the steel is claimed to be entirely beneficial, not only preventing the formation of scale, but tending to remove scale already formed. The patent referred to, although entitled " a process for annealing steel," very curiously has nothing to say about the cooling of the steel after it has been thus heated. — " The American Machinist," April 14, 1904.

**Acid v. Basic Steel Rails in Sweden.** — Messrs. Bolling & Lowe, the well-known iron merchants, have kindly sent us a translation from the South Swedish newspaper " Snallposten," on the subject of " Basic v. Bessemer Acid Rails." The Swedish Government and nearly all the Swedish State Railways have hitherto used Bessemer acid rails, and the orders have always come to this country, with the exception of occasional orders to the Société Anonyme John Cockerill, of Seraing, Belgium, which were the only Continental works for some time who made rails by the Bessemer acid process. It now looks, however, as though the Swedish Government were going to give basic rails a trial, as several orders have lately been placed for this class of material. The translation follows:

" The railway authorities are now making trials for the purpose of comparing acid and basic steel rails. These trials will probably extend over a period of about a year, and the authorities are considering the advisability of sending a special engineer to visit various countries for the purpose of studying the question, which is an exceedingly important one from a national economical standpoint. The object is, of course, to ascertain whether it is possible to purchase material for the State railways more cheaply than hitherto, and, of course, it is a well-known fact that basic steel is considerably cheaper than that produced by the acid process. The State railway authorities have, however, from a desire to ensure the safety of the traffic, until now exclusively used acid rails. A few years ago, trials were made with basic rails which were laid for about 25 kilometers, but the result of this trial was not altogether convincing one way or the other. The usual (acid)

rails showed 7 to 11 breaks in 10,000 rails laid down, while
the number of breaks in a similar number of basic rails was 65;
an enormous difference, and one which naturally had a great
effect upon the safety of the traffic. This, of course, is the
first consideration, for, although one might save a very large
sum in the first cost, it might very easily be lost in the case
of a bad accident caused by a broken rail. It is now main-
tained that the defects which caused the high percentage of
breakages at the first-mentioned trials have been remedied in
the system of manufacture, and it will be this question that
the forthcoming trials will have to decide." — " The Iron and
Coal Trades Review," March 18, 1904.

# REVIEW OF THE IRON AND STEEL MARKET

Although somewhat prepared for the outcome, the iron trade was nevertheless startled by the practical disruption of the Lake Superior Ore Association at its brief meeting on May 3. Since early in the year it had appeared certain that conditions were such that a substantial reduction in ore prices, as compared with the average of the years 1900 to 1903 inclusive, would be necessary, but the balance of opinion was rather that such reduced prices would be under association control. After all interests had become reconciled through force of circumstances to reductions of $1.00 a ton on old range Bessemer ore and 75 cents on Mesabi-Bessemer, with slightly smaller reductions on non-Bessemers, it developed that it would be impossible to agree upon allotments, the rock on which so many trade agreements have gone to pieces when a heavy reduction in the total production was a necessity.

The gist of the matter is that the Lake Superior ore producers have given up all efforts to control prices for this season, and the organization will be kept alive for statistical purposes only. Circumstances are held by the trade to determine that there will be no price control in immediately following years either. Consumers had no great objection to the high prices of the past four years, when they had a substantial assurance that all new buyers would have to pay them, and that there would be no serious declines from year to year. Now, however, with about 10,000,000 tons of ore unused on May 1, yet bought and paid for at the high prices of last season, and low prices available for the present season, they are confronted with an enormous loss and will not take kindly to any future efforts at price regulation. Furthermore, the making of long-term contracts for ore has been stimulated, and by the end of this season such contracts covering several million tons annually will have been made. Most of those who have recently built blast-furnaces have concurrently acquired an ore supply on favorable terms, and with the halt to our increase in consumptive demand it would appear

that for some years to come substantially all the Lake Superior ore consumed will have reached the blast-furnace on terms considerably more favorable than would be the case with season purchases, by direct ownership of mines by blast-furnace interests, by joint ownership, and by long time contracts.

During the period of our exceptional prosperity extending over four or five years, the iron and steel market has been largely influenced by the prices which certain furnaces, lacking their own supplies of ore, have had to pay. The cost of production to such less favorably situated furnaces has marked out the minimum possible price of pig iron, and the actual price has been, in general, much above this level. In the changed conditions, a new level has been established, and this new level is not far from the level of the years 1896, 1897 and 1898, not far from $10 a ton. There is possible, therefore, and even probable, a decline in pig iron prices within the next few months of anywhere from $1.00 to $3.00 a ton. Since the apex of demand there has been an increase in capacity which will reach, with furnaces now being built and certain of completion, fully 4,000,000 tons of pig iron annually, and close competition between producers is certain.

The special advantage which has been held by a large class of producers, through their control of ore supplies, is largely wrested from them, and opportunity is more widely distributed than for several years. Long time contracts are being negotiated on the basis of about $2.75 for Mesabi-Bessemer, f. o. b. lower lake ports, against $4.00 in 1903, and a market for other ores will gradually develop.

There is no question that, from a commercial standpoint, the most important development in the iron and steel trade for several years has been this disappearance of high prices for ore in the season market. The artificial control of the billet market is endangered, and with it the maintenance of prices on many finished steel products.

Production during April marked the culmination of a steady increase since the first of the year, which brought the rate close to the average of the past two years and since the first of May new buying has been almost lacking, pointing unmistakably to the necessity for a decrease in production. During May producers have operated almost entirely on back orders, and in the

absence of important transactions all market quotations are more or less nominal as reported below.

*Pig Iron.* — Asking prices are about as follows: At valley furnace: Bessemer, $12.75; basic, $12.50; No. 2 foundry, $12.50; at Pittsburg: Bessemer, $13.60; basic, $13.00 to $13.35; No. 2 foundry, $13.35 to $13.50; forge, $12.50; at Philadelphia: No. 2X foundry, $14.75; standard forge, $13.25; basic, $13.50; at Chicago: (northern iron) No. 2 foundry, $13.50; malleable Bessemer, $13.75; Lake Superior charcoal, $15.00; at Birmingham: No. 2 foundry, $9.25; forge, $8.50; basic, $9.00; freight from Birmingham to Chicago, $3.65 (a reduction of 20 cents); to Pittsburg, $4.35; to New York, $3.25.

*Steel.* — Billet association prices are being shaded occasionally from 50 cents to $1.00 a ton, and are, delivered Pittsburg, Wheeling, valleys, Johnstown, Ashland and Lorain, $23.00; Cleveland, $23.50; Chicago, $24.00; Philadelphia and Baltimore, $24.25; New York, $24.75; New England points, $25.25. These prices cover Bessemer and open-hearth billets 4 × 4 and larger, 0.25 per cent carbon and under; small billets and sheet bars, long lenths, are $1.00 extra, and shearing to specifications is 50 cents additional.

*Finished Materials.* — Merchant bars: Bessemer steel, 1.35 cents; open-hearth steel, 1.40 cents; both f. o. b. Pittsburg; common iron bars, 1.30 cents at mill, all base. Plates, tank quality, and beams and channels, 15-inch and under, 1.60 cents, Pittsburg. Sheets, No. 28 gauge, 2.20 cents at mill for black, and 3.20 cents for galvanized; tin plate, $3.45 for 100-pound cokes, at mill.

# STATISTICS

**Two Years' Drawback Operations.** — Below we present a table showing iron and steel products on which drawback was paid during the fiscal years 1902 and 1903. The law provides that on the export of any article made partly or wholly from imported materials, there shall be paid to the exporter, on the export of the article, a drawback equal to 99 per cent of the duty originally paid on the imported material. Of late years the law has been more liberally interpreted than formerly. The presentation is substantially complete, but inasmuch as it refers only to weight, there are some omissions of articles the weight of which is not presented in the Government returns. Such omissions include some brakework, wheels and axles, locomotive parts, tubing, etc., but the total value thereof did not equal $100,000 in 1902, or $10,000 in 1903.

The figures refer to gross tons of 2,240 pounds, for the fiscal years ended June 30, as follows:

|  | 1902 | 1903 |
|---|---|---|
| Iron ore | 271,228 | 5,247 |
| Ferromanganese | 106 | 1 |
| Spiegeleisen | 2,682 | 266 |
| All other pig iron | 1,286 | 8,294 |
| Scrap iron and steel | 1,987 | 2,675 |
| Bar iron | 4 | 76 |
| Steel billets | 186 | 23,386 |
| Blooms and slabs, etc. | .... | 3,095 |
| Hoop, band or scroll | .... | 2,148 |
| Locomotive wheels and tires | 107 | 205 |
| Wheels and axles | 11 | .... |
| Rails | 4 | 773 |
| Wire rods | .... | 1,283 |
| Sheets | 69 | 536 |
| Structural iron and steel | .... | 855 |
| Taggers iron | 183 | 115 |
| Tin plates | 55,956 | 54,950 |
| Steel tires | 14 | 179 |
| Steel tubing | .... | 5 |
| Wire | 540 | 130 |
| Total, not including ore | 63,135 | 98,972 |

**Bessemer Steel Rail Production.** — A correction must be made to the statement of Bessemer steel rail production in the United States in 1903, as presented on page 555 of our May issue. The mistake was not made by us nor by the American Iron and Steel Association, which gathers and presents the statistics, but by the person who reported the production of the Edgar Thomson steel works, in stating the tonnage at 675,214 tons instead of 734,859 tons. Therefore the tonnage of Bessemer steel rails made by the producers of Bessemer steel ingots should be 2,873,228 tons, or 59,645 tons more than we reported last month, making the total for 1903 only 3,065 tons less than in 1902. The statistics of Bessemer steel ingot production are not affected by the error now discovered.

# RECENT PUBLICATIONS

*Album of Drawings Relating to the Manufacture of Open-Hearth Steel.* Part I, Open-Hearth Furnaces, by M. A. Pavloff, High School of Mines, Ekaterinoslav, Russia. 1904. 52 15 × 11 in. plates and 8 pages of descriptive matter. Price, $3.00. — These valuable drawings of Open-Hearth Furnaces form a companion album of high merit to the Album of Drawing relating to Blast-Furnace practice previously published by Professor Pavloff. The drawings include the following plates: The development of Open-Hearth construction showing the designs of a ½-ton furnace built by Martin at the Sireuil Steel Works (France) and later (1870) at Votkinsk (Ural), a 2½-ton furnace designed by W. Siemens and built in 1870 at Sormovo (Central Russia) and a 15-ton furnace built at Sulin (South Russia); a 20-ton furnace built at many German and Russian Works; a 30-ton furnace of the Donawitz Iron and Steel Works (Austria); a 20-ton furnace of a Sulin Iron and Steel Works (South Russia); a 25-ton furnace of the Volga Steel Works (Saratov, Russia); a 12-ton Basic Open-Hearth Furnace of the Ougrée Company (Ougrée, Belgium, and Taganrog, Russia); a 20-ton Basic Furnace of the Krompach Open-Hearth plant (Hungary); a 25-ton furnace of the Lissva Open-Hearth plant (Ural); a 50-ton Basic Campbell Furnace of the Pennsylvania Steel Co. (Steelton, Pa.); a 50-ton Basic Wellman Furnace of the Alabama Shipbuilding Co. (Ensley, Alabama); a Tilting Open-Hearth Furnace with Chromite blocks bottom built in 1896 at the Seversky Works (Ural). Many drawings are also included showing detailed construction of roof, bottom, walls, ports, regenerators, slag pockets, valves, etc. The description is printed in French, English and Russian.

*The Metallurgy of Steel,* by F. W. Harbord; 760 6 × 9 in. pages. Illustrated. Charles Griffin & Co. London. 1904. Price, $9. — The treatment of the subject is divided into four parts: I, The Manufacture of Steel; II, Reheating; III, The Mechanical Treatment of Steel, and IV, Finished Steel. Parts I
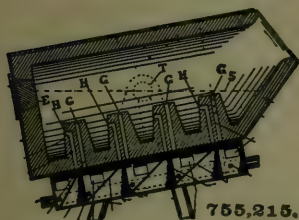
and IV were written by Mr. Harbord, Part III by Mr. J. W. Hall and Part II jointly by both writers. Part I deals exhaustively with the various methods of producing steel, both from the theoretical and the practical point of view. Part II is devoted to a description of reheating furnaces and the handling of material in reheating operations. In Part III the mechanical treatment of steel is considered at length, and presented with much authority and clearness. Part IV is devoted to the study of the finished steel and includes mechanical testing, the influence of many elements on the properties of steel, steel alloys, heat treatment and the microscopical examination of steel. The treatment of the subject is characterized by its exhaustiveness, clearness and soundness, and the authors are to be congratulated on the production of so valuable a book. The publishers also have done justice to the importance of the text, the typography, paper and binding being excellent.

# PATENTS

## RELATING TO THE METALLURGY OF IRON AND STEEL

### UNITED STATES

755,215. CONVERTER FOR MAKING STEEL, ETC. — Walter B. Burrow, Norfolk, Va. A horizontally-operated centrally-pivoted converter for making malleable iron and steel having vertical and horizontal twyers in the direction of the length of the converter, the said converter or vessel revolving completely through different angles on its axis or trunions.*

755,244. DEVICE FOR SEPARATING FLUE-DUST FROM GAS. — William A. Riddell and Joseph Riddell, Sharon, Pa. A device for separating flue-dust from the gas coming from a blast-furnace, comprising a closed tank having a water-inlet and a water-outlet whereby water is maintained in said tank at a determined level, a pipe extending horizontally in said tank slightly above said water-outlet, said pipe being stationary and having an opening in its lower side only directed against the surface of the water, a gas-inlet to the pipe and a gas-outlet from the tank.*

755,368. INGOT-PERFECTING MACHINE. — Robert W. Hunt, Chicago, Ill. An ingot-perfecting machine, comprising a suitable frame that is movable above the ingot-mold stand, in combination, with means for moving said frame, to position the same, an elongated rod-cozy carried by said frame and a rod-driver also provided in said frame, for driving a rod from said cozy into an ingot placed beneath it.*

755,433. FORGING APPARATUS. — James H. Baker, Pittsburg, Pa. A swaging-roll provided with a pivoted hook adapted to engage and draw the blank.*

755,436. ART OF MANUFACTURING TUBES. — Lewis O. Bentel, Pittsburg, Pa., assignor of two-thirds to John M. Petty and W. A. Caven, Pittsburg, Pa. A method of making a tube which consists of forming lips on the lateral edges of a tube-sheet, the lips on one of said edges being narrower than said other edge, said lips being respectively adjacent to the opposite faces of said sheet and their combined thickness being greater than the thickness of said sheet, whereby when said sheet is bent up into tubular form, and said lips overlap, a recess is left between the edge of said narrower lip and the opposing shoulder on the opposite edge of said sheet, and subjecting said lips to a welding action whereby the surplus

thickness of metal in said lips is so forced down that said recess is filled and said lips are united into a combined butt and lap weld.*

755,496. APPARATUS FOR PERFECTING INGOTS. — Robert W. Hunt, Chicago, Ill. An ingot-perfecting apparatus, comprising a stripping-machine, in combination with a rod or billet holder for operation between the same and the top of the ingot-mold.*

755,629. PROCESS OF ANNEALING STEEL. — Leonard D. Davis, Erie, Pa. A process of annealing steel which consists in immersing steel in a bath of molten metal which fuses between 1,000° and 1,500° F. and gradually cooling steel.*

755,702. GAS PRODUCERS. — James G. Sanderson, Scranton, Pa. A gas-producer comprising a fuel-chamber having a continuous wall formed of a series of circumferentially-arranged individual water-tubes located in direct contact with each other and provided with passages for the ingress and egress of water therefrom, and hands encircling and impinging against the wall for holding the tubes in place.*

755,722. PROCESS OF MAKING METAL CASTINGS. — George Stroh, Syracuse, N. Y. A process of making metal castings consisting in introducing under the molten metal to be cast, a fluent or semi-fluent material of greater specific gravity and applying to the said introduced material artificial pressure sufficient to force the overlying molten metal into the mold or matrix.*

755,763. PROCESS OF TEMPERING OR HARDENING CAST IRON. — William Gilmour and Alexander Lindsay, Montreal, Canada, assignors of one-half to Charles Augustus Myers and Herbert Henry Bradfield, Morrisburg, Canada. A process of hardening or tempering cast iron which consists in heating the metal, then dipping it in a bath consisting of a practically anhydrous acid of high heat conducting and absorbing quality in which is dissolved a heavy metal.*

755,842. APPARATUS FOR CASTING METALS IN VACUUMS. — Walter B. Burrow, Norfolk, Va. A vacuum casting apparatus, the combination of a metallic outer drag, box or case, a flange or lip projecting outward forming a flared rim at the top of the said drag, a detachable cope, bonnet or top over and entirely inclosing the mold in its flask or box, the said outer cope or top fitting into a space on a sand filling around and between the inner mold flask and the outer drag or box, and a metallic seal at the junction of the outer cope or top and the outer drag or box, of a lower metaling-point than the said top part or cope and the lower part or drag.*

755,871. APPARATUS FOR TREATING ORE. — Thomas A. Helm, Salt Lake



City, Utah. An apparatus for treating pulverized auriferous ores, comprising a rotatable cylindrical tank, radially-depending blades in the tank extending the length thereof, a circular brac-frame disposed between the inner ends of the radial blades, an air pipe leading into the tank, faucets to draw off a liquid from the tank and means to rotate the tank.*
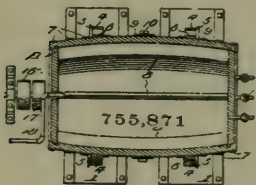
755,867. METALLURGICAL APPARATUS. — George W. Gesner, New York, N. Y., assignor to Harleston Corbett Gesner, Brooklyn, N. Y. An apparatus for manufacturing hydrogen alloy, a furnace, a large flue leading therefrom, an upright retort mounted concentrically in such flue, and a coil of pipe embedded in the material of such retort, with provisions for passing steam through such coil into the retort.*

755,951. PROCESS OF TREATING ORES. — Joseph Smith, San Francisco, Cal. In the cyanide treatment of ores, the method of rendering insoluable in the cyanide solution, ferrous oxid contained in a mass of moist crushed ore, which method consists in applying heat to said mass in the presence of air previous to its treatment by the cyanide solution.*

756,110. METHOD OF EXTRACTING MOISTURE FROM AIR FOR BLAST-FURNACES AND CONVERTERS. — James Gayley, New York, N. Y. A method of feeding the air-blast to blast-furnaces or converters, which consists in



756.110.
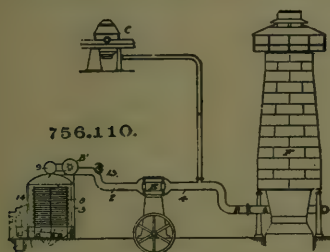
cooling the air artificially, thereby causing its moisture to be reduced to a small percentage, feeding the dried air to a blowing engine by initial pressure of relatively small degree sufficient to overcome in whole or in part the friction of the air-current in the apparatus, increasing its pressure at the blowing-engine to a degree above that to which it was initially subjected and feeding the dried air therefrom under compression into the furnace or converter, and maintaining it under compression from the time it leaves the blowing engine until it enters the furnace or converter.*

756,211. PRECIPITATING METALS FROM SOLUTIONS. — Chas. Butters, Berkeley, Cal. An improvement in the process of precipitating metals from solutions, chiefly cyanide solutions, which consists in employing cathodes having surfaces of tin and a high-density electric current.*

756,271. APPARATUS FOR TREATING SOLIDS, SUCH AS ORES, LIQUIDS, OR GASES. — Paul Naef, New York, N. Y. In combination with an apparatus for treating liquids, and solids, a settling-tank, an inclined bottom on said tank and means to run sludge from said tank back to the apparatus.*

756,473. MANUFACTURE OF SHEET IRON. — Walter Clasper, McKeesport, Pa. A process of making blued sheet iron or steel, which consists in annealing the sheets, and subsequently raising the sheets separately to a low cherry-red heat by passing them singly and processionally and at the same rate of speed with both faces exposed through a furnace having a mild diffused heat therein, and then insuring the proper blued surface by exposing them to slow air-blast cooling.*

756,474. APPARATUS FOR THE MANUFACTURE OF SHEET IRON. — Walter Clasper, McKeesport, Pa. In apparatus for making blued sheet-iron, the combination of a heating-chamber, means for maintaining a uniform heat of said chamber, air-blast apparatus adjacent to said chamber, and mechanism for carrying the sheets in single procession through said heating-chamber and to and past said air-blast mechanism.*

* " Engineering and Mining Journal."

## GREAT BRITAIN

8,026 of 1903. Steel Making. — H. W. Lash, Cleveland, Ohio, U. S. A. Making steel from low quality ores, by mixing Bessemerized metal with a charge of pig iron in basic open-hearth furnace.*

8,298 of 1903. Steel Alloy. — T. J. Tresidder, Sheffield. A steel containing nickel, manganese and tungsten, that will not become crystalline during the sudden chilling from very high temperatures.*

4,894 of 1903. Puddling Furnace. — J. Jones, Tipton. In puddling and other furnaces, providing air passages in the structure, which will heat the air and promote combustion of the fire.*

26,037 of 1903. Tuyère. — E. Bertrand and E. Vorbach, Kladno, Bohemia. Improved nozzle for tuyères of blast-furnaces, which can regulate to a nicety the amount of air passing in.*

9,346 of 1903. Steel Making. — C. J. L. Otto, Dresden, Germany. Producing steel direct, in a crucible, by acting on iron ores mixed with scrap, with a hot-air blast, the metal being out of contact with the reducing fuel.*

### Application for Patents

6,968. Improvements in Apparatus for Unloading and Distributing Steel Rails. — H. Ware, London.†

6,981. Improvements in Gas-Producers. — R. Kennedy, Leeds.†

6,999. Improvements Relating to Gas-Producers and like Apparatus. — A. L. Forster, London.†

7,079. Improvements in Gas-Producers. — I. W. Whitworth, Manchester.†

7,291. Improvements in Rolling Mills. — O. Briede, London.†

7,367. An Improved Process and Apparatus for Smelting Ores, More Particularly Iron Ores. — O. Simmersbach, London.‡

7,412. Improved Means for Removing Molten Slag or Metal from Open-Hearth Furnaces. — J. H. Beckett, Rotherham.†

7,426. Improvements in Regenerative Gas Furnaces for Melting Steel and Like Purposes. — J. Izzett, Glasgow.||

7,478. Improvements in the Manufacture of Briquettes from Powdered Iron Ore or Iron Wastes of from Iron Sand or Mixtures Thereof for Reduction in Furnaces. — T. Rouse and H. Cohn, London.†

7,649. Improvements in Crucible Furnaces. — M. Harvey, Birmingham. ‡

### Complete Specifications Accepted

11,297. Blast-Furnaces. — Garretson.†

## FRANCE.

662. Rolling Mills for Weldless Tubes. — O. Briede.

670. Manufacture of Welded Tubes. — H. Kamp.

765. Method of Cementation for Large Surfaces and Furnace for the Conduct of the Operations. — L. F. Ladoire.
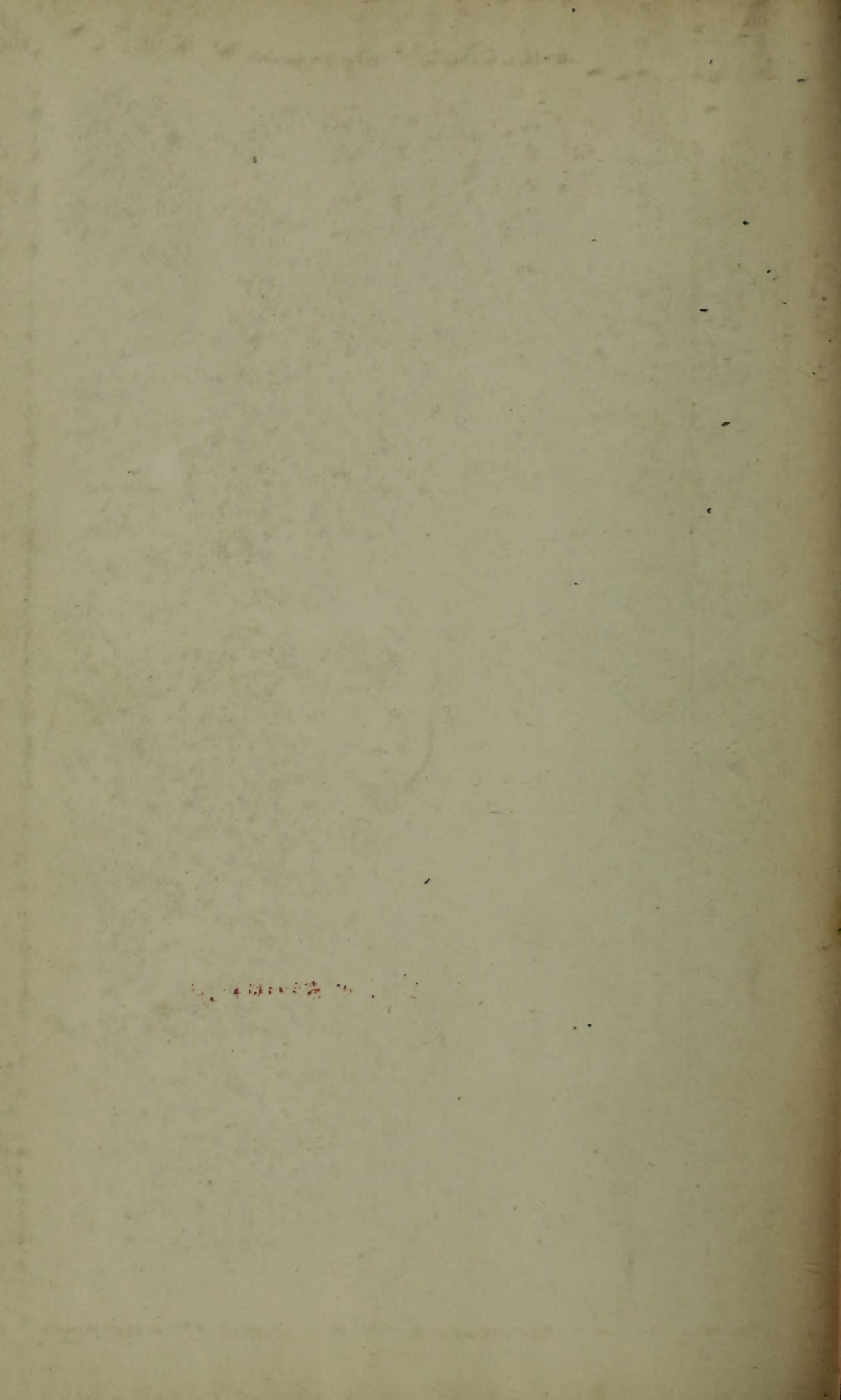
770. Molding Machine. — T. Trimmins.

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\* "The Engineering and Mining Journal."          ‡ *Ibid,* April 8, 1904.
† "The Colliery Guardian," April 1, 1904.          || *Ibid,* April 9, 1904.